# Hydro Life Extension Modernization Guide

## Volume 6 - Civil and Other Plant Components

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# REPORT SUMMARY

Hydroelectric power generation is a proven vital source of electricity in the United States and worldwide. This guideline represents the last in a series of seven to help hydroelectric utilities access the needs and benefits of life extension and modernization. This volume focuses on alternatives for civil and other plant components to assist in evaluating the cost and economic justification for various alternatives and to implement the selected plan. It also provides a screening procedure and criteria to enable utility personnel to identify which hydroelectric plants may be suitable for modernization and which plants promise the most immediate return on investment.

## Background

*Volume 6 Civil and Other Plant Components* is the last in a series of guidelines for assessing the needs and benefits and evaluating the cost and economic justification of life extension and modernization (LEMS) alternatives. It covers the civil components, particularly the intakes, spillways, dams, powerhouses and water conveyances. It also provides a screening procedure and criteria to enable utility personnel to identify opportunities for modernization.

Hydroelectric power generation is a proven vital source of electricity in the United States and throughout the world. Many hydroelectric plants have been reliably generating electricity for more than 50 years. Because these facilities continue to age, decisions must be made concerning retirement, continued maintenance and operation, or modernization and redevelopment. Experienced personnel retire and leave utility companies, and so the need for guidance in making these critical decisions becomes even more important.

There is a crucial need for guidance in helping utility managers and owners make critical decisions regarding the future of their plants. In 1989, EPRI issued three volumes of modernization guidelines that have been widely used by the industry. This series of guidelines updates the 1989 guides and expands them to cover the entire plant.

## Objectives

- To provide technical information and data on the civil and other plant components, particularly the intakes, spillways, dams, powerhouses and water conveyances, that can be used as input for the LEM of hydropower plants anywhere in the world.
- To compile the information on available and developing technology
- To develop guidelines to assess needs for LEM and develop a cost-effective life cycle plan
- To provide technical data and information required for implementation

- To identify license implications of any upgrades
- To identify improvements that can decrease environmental impacts
- To produce a resource tool for experienced and novice utility engineers

## Approach

The preparation of this volume of the Hydro Life Extension Modernization Guides is a joint approach with the Hydropower Committee of the American Society of Civil Engineers (ASCE) Energy Division. The technical information in this volume was prepared as part of the ASCE Guidelines for Life Extension and Upgrade of Civil Works for Hydroelectric Facilities. The remaining information was supplied as a result of an extensive search and review of literature on civil and other plant components, particularly the intakes, spillways, dams, powerhouses and water conveyances.

## Results

This volume of *Hydro Life Extension Modernization Guides* provides technical information for the LEM planning process described in Volume 1 and guides the user in establishing a base case, pinpointing high value alternatives, incorporating them in the overall LEM plan, Guidance on selection and procurement of equipment and services as well as implementation of the LEM plan is also provided. Throughout the process, the focus is on creating value by applying technologies that offer the greatest return. This requires an understanding of the technologies and their application as well as an awareness of markets and the need to match technology to market demand.

## EPRI Perspective

Deregulation and the privatization of the electricity industry around the globe present threats but also opportunities. As energy markets develop, demands must be met instantaneously and reliably, and hydro assets will increase in value. A comprehensive set of guidelines for the LEM of hydro plants can help to ensure that plants have the equipment and the processes they need to supply electricity to the modern world, therefore ensuring hydra's ability to capture its deserved market share.


## Keywords

Asset Management

Civil and Other Plant Components

Intakes

Spillways

Powerhouses

Water Conveyances

Water Control Devices

Hydropower

Life Extension

Modernization

# ABSTRACT

Under contract to EPRI, BC Hydro has developed a seven-volume set entitled *Hydro Life Extension Modernization Guides*. These documents, superseding the three volume 1989 Guides published by EPRI, will enable utility personnel to identify the hydroelectric plants that are potentially suitable for modernization because they promise the most immediate return on investment. They will also provide guidance on the design and implementation of the selected plan. Volume 6 covers the civil and other plant components, particularly the intakes, spillway dams, powerhouse and water conveyances. This Volume was prepared in association with the Hydropower Committee of the American Society of Civil Engineers (ASCE) Energy Division.

# ACKNOWLEDGEMENT

This report is the result of a joint approach with the Hydropower Committee of the American Society of Civil Engineers (ASCE) Energy Division. Technical information has been prepared by the ASCE as part of the Guidelines for Life Extension and Upgrade of Civil Works for Hydroelectric Facilities. In addition, a number of individuals provided information and contributed to the production of this report. Valuable input and comments were received from BC Hydro Engineering and Christensen Associates Inc. EPRI staff reviewed this document.

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# 1
# CHAPTER 1: INTRODUCTION AND SCOPE

## 1.1 Volumes 1 to 7

Volume 1 of *Hydro Life Extension and Modernization Guides,* referred to subsequently as 'Volume 1', addresses how to formulate an integrated plan for an entire hydropower plant. It did not cover the technical specifics for each plant area, but it required that detailed technical information be acquired.

Volumes 2-7 of these guidelines provide the detailed information required to successfully use Volume 1. The subject matter of Volumes 2-7 is:

- Volume 2: Hydromechanical equipment
- Volume 3: Electromechanical equipment
- Volume 4: Auxiliary mechanical systems
- Volume 5: Auxiliary electrical systems
- Volume 6: Civil and other plant components
- Volume 7: Protection, control and automation

## 1.2 Volume 6: Civil and Other Plant Components

The primary civil and other plant components covered in this report are:

- structures, including intakes, dams, spillways, and powerhouses
- water conveyances, including canals, conduits, tunnels and penstocks
- water control devices, including gates, gate hoists, valves and operators, and
- civil works system

## 1.3 Joint Approach with ASCE

The preparation of this Volume of the Hydro Life Extension and Modernization Guidelines has been undertaken jointly with the Hydropower Committee of the American Society of Civil Engineers (ASCE) Energy Division. The technical information in this volume is aligned with the ASCE Guidelines for Life Extension and Upgrade of Civil Works for Hydroelectric Facilities and corresponds with the approach taken for the remainder of the EPRI Guides.

## 1.4 Purpose of Volume 6

Volume 1 provides the overall process for developing a life extension and modernization (LEM Plan) for a plant. Technical information is required for most of the steps in the process so that the needs (life extension requirements) and opportunities (modernization possibilities) of the plant can be clearly defined and addressed in terms of actual activities or plant projects.

Volume 6 describes technical information and data on civil and other plant components that can be used as input to the LEM planning process as developed through Volume 1. Volume 6 is used after the screening of facilities and the selection of plants suitable for LEM studies are completed and described in Volume 1, Chapter 3. Volume 6 is a technical resource to assist engineers and planners with the development of the LEM plan for a particular plant. Volume 6 also assists in the design of projects for implementation.

Volume 6 can also be used as a stand-alone document for the assessment and review of the rehabilitation/upgrade options for civil and other plant components, outside of the overall development of a plant LEM Plan.

## 1.5 How to Use Volume 6

Figure 1-1 shows how the various parts of Volume 6 provide information to support the development of the LEM Plan. This flowchart should be referred to on an ongoing basis as the user works through the assessment and other technical aspects of Volume 6 to ensure that all necessary information is fed back into the Volume 1 process. The flowchart is adapted from the flowchart in Figure 1-2 of Volume 1 of these Guidelines.

Volume 6 provides guidance to identify and define projects that either extend civil plant service life (life extension) or upgrade the equipment and structures (modernization) in terms of performance. The general steps are: screening; evaluation of condition and performance; evaluation of "upgradability" and modernization potential; estimation of costs and benefits; feasibility studies and implementation.

Volume 6 includes the following chapters that support these steps:

Chapter 1, "Introduction" - The needs, concepts, objectives and scope of Volume 6 are explained. The user will gain an understanding of the content of the volume and whether or not it will be applicable to the user's needs, and how to use these Guidelines.

Chapter 2, "Background to Life Extension and Modernization" - This chapter summarizes a utility's approach to LEM, including the policies and principles that should be in place. This subject is covered in greater depth in Volume 1 of the Guides.

Chapter 3, "Screening" - In this first step of the LEM process, the user obtains the necessary information about the civil aspects of the plant. In many cases this information will justify proceeding directly to undertaking a more detailed evaluation of condition and performance.

Where it is uncertain, the user is led through the necessary steps of a desktop study to screen and prioritize the civil aspects of the plant in terms of those most likely to yield benefit from LEM.

Chapter 4, "Life Extension and Modernization (LEM) Processes" summarizes the approach taken in the previous EPRI Guidelines, to assess the condition, risk profile and performance of the hydroplant and develop the appropriate LEM plan.

Chapter 5, "Aligning EPRI Guide Volume 6 with ASCE Guide" summarizes the contents of the ASCE document and provides references and hyperlinks as appropriate.

Appendix A, "Case History based on EPRI Process" - An example of the approach to evaluating life extension and modernization option for selected civil works using the EPRI process, with input from the ASCE Guides.

Appendix B, "Literature Review" - An annotated bibliography of case histories, reports of new technologies and processes, and other published papers for further reading are presented.

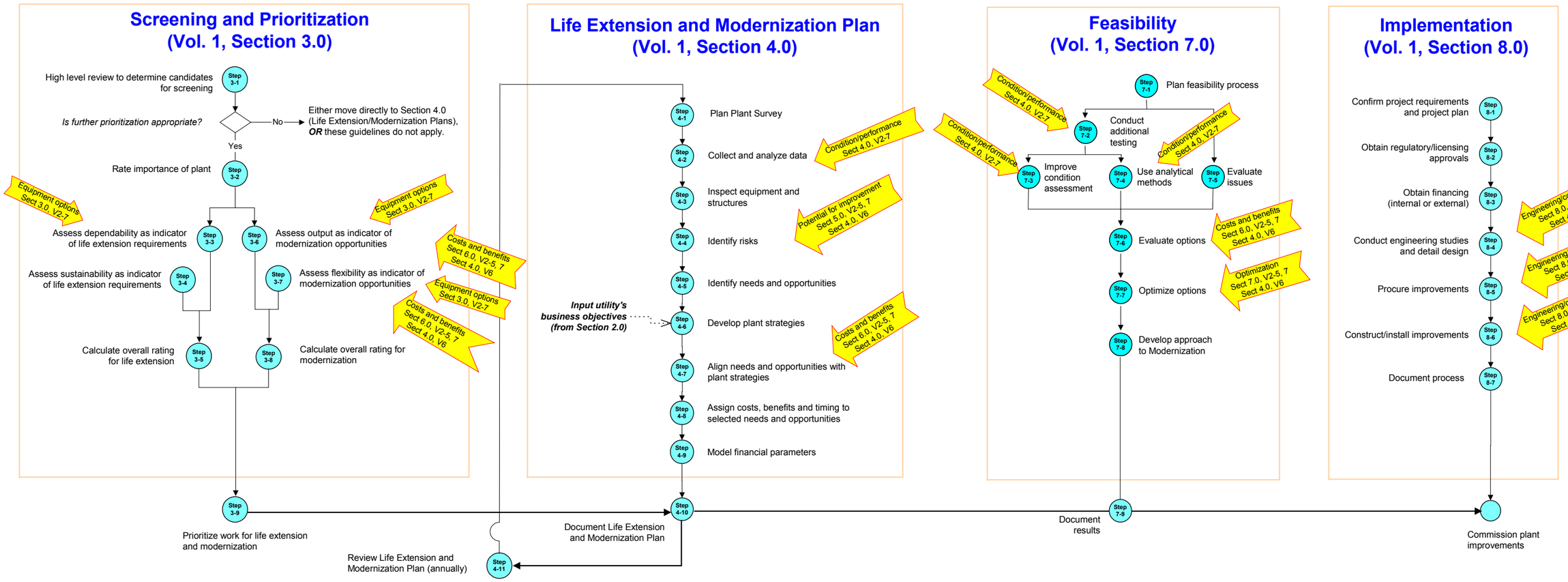
## 1.6 Definitions

In the hydropower industry, the terms "life extension", "rehabilitation", "modernization", "upgrade", "upgrading" or "uprating", are used to indicate the nature, extent, or result of an improvement to a hydro plant or component. These terms are frequently used interchangeably. For this report, the following are the "improvement" terms that are used:

*Life Extension* is defined as the replacement or improvement of components that have been the cause of higher maintenance repair, or for which failure, due to age, is expected in the forseeable future. Other terms that are close in meaning and often used interchangeably with life extension include rehabilitation, retrofit, replacement and refurbishment. The term *overhaul* has a slightly different meaning and usually refers to the planned disassembly, cleaning, repair, lubrication and re-assembly of a unit or component.

*Modernization* is defined as the improvement of level of service and cost of service (refer to Volume 1, Chapter 2.3.1) measured by plant output and/or flexibility. Other terms that are close in meaning and often used interchangeably with "modernization" include upgrade, upgrading and uprating.

*Redevelopment* is defined as new construction of an existing plant, including replacement or substantial modification of civil, mechanical, and electrical components. Redevelopment is not covered by these Guidelines.


Screening and Prioritization
(Vol. 1, Section 3.0)
High level review to determine candidates for screening
Step 3-1
Is further prioritization appropriate?
No
Either move directly to Section 4.0 (Life Extension/Modernization Plans), OR these guidelines do not apply.
Yes
Rate importance of plant
Step 3-2
Equipment options Sect 3.0, V2-7
Equipment options Sect 3.0, V2-7
Assess dependability as indicator of life extension requirements
Step 3-3
Step 3-6
Assess output as indicator of modernization opportunities
Costs and benefits Sect 6.0, V2-5, 7 Sect 4.0, V6
Assess sustainability as indicator of life extension requirements
Step 3-4
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Equipment options Sect 3.0, V2-7
Costs and benefits Sect 6.0, V2-5, 7 Sect 4.0, V6
Calculate overall rating for life extension
Step 3-5
Step 3-8
Calculate overall rating for modernization
Step 3-9
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Life Extension and Modernization Plan
(Vol. 1, Section 4.0)
Step 4-1
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Condition/performance Sect 4.0, V2-7
Step 4-2
Collect and analyze data
Step 4-3
Inspect equipment and structures
Potential for improvement Sect 5.0, V2-5, 7 Sect 4.0, V6
Step 4-4
Identify risks
Step 4-5
Identify needs and opportunities
Input utility's business objectives (from Section 2.0)
Step 4-6
Develop plant strategies
Costs and benefits Sect 6.0, V2-5, 7 Sect 4.0, V6
Step 4-7
Align needs and opportunities with plant strategies
Step 4-8
Assign costs, benefits and timing to selected needs and opportunities
Step 4-9
Model financial parameters
Step 4-10
Document Life Extension and Modernization Plan
Step 4-11
Review Life Extension and Modernization Plan (annually)
Feasibility
(Vol. 1, Section 7.0)
Step 7-1
Plan feasibility process
Condition/performance Sect 4.0, V2-7
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Condition/performance Sect 4.0, V2-7
Condition/performance Sect 4.0, V2-7
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Step 7-4
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Step 7-5
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Step 7-8
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Step 7-9
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Obtain regulatory/licensing approvals
Step 8-2
Obtain financing (internal or external)
Step 8-3
Engineering/construction Sect 8.0, V2-5, 7 Sect 4.0, V6
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Step 8-4
Engineering/construction Sect 8.0, V2-5, 7 Sect 4.0, V6
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**Figure 1-1**
**LEM Flowchart**

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# 2
# CHAPTER 2: BACKGROUND TO VOLUME 6

## 2.1 Introduction

Volume 6 describes the main civil and other plant components of a hydro development. These include intakes, spillways, dams, powerhouses and water conveyances.

It is assumed that the user of the Guidelines has a basic understanding of civil works, therefore detailed descriptions of the equipment and structures are not provided.

## 2.2 Objectives of Hydro Life Extension and Modernization

Each hydro life extension and/or modernization program or project has its own, sometimes unique, objectives. Among possible objectives for a specific project are:

- Plant Life Extension and Restoration of Original Performance Levels
  - To extend structure and equipment life
  - To halt or decelerate deterioration
  - To reduce operating and/or maintenance costs
  - To reduce frequency of major maintenance and scheduled downtime
  - To reduce undesirable operating characteristics
- Plant Modernization to Improve Plant Products and Economics
  - To increasing generating capacity
  - To improve efficiency
  - To improve ability to deliver "ancillary services"
  - To improve plant/personnel safety
  - To avoid obsolescence problems such as lack of manufacturer support or unavailability of replacement parts
- Risk Management and Environmental Compliance
  - To reduce risk of catastrophic failure
  - To improve ability to meet river flow or reservoir level requirements
  - To reduce potential for environmental degradation

- To enhance water quality
- To reduce aquatic impacts
- To meet legal/licensing requirements

## 2.3 Trends in Life Extension and Modernization

An industry benchmarking survey was conducted in conjunction with the HydroVision 98 conference. The survey, based on the 66 reported projects, provides a good sampling of general approaches and practices being implemented by hydro owners, primarily in North America, with regard to plant or component LEM. Relevant information about each project is provided in TR-113584-V2, *Hydropower Technology Round-Up Report, Part 2: Rehabilitating and Upgrading Hydro, 1998.* The report presents statistics on the reasons for life extension and/or modernization, strategies employed, economic and prioritization criteria, contracting arrangements, quality control and testing methods.

Section 5.3 of this Volume presents a summary of innovative technologies, specifically related to civil works. Areas where perhaps the most significant recent trends have occurred are:

- automation of instrumentation and monitoring
- improved methods of assessing condition and performance
- advances in the identification and treatment of AAR and associate concrete growth phenomena
- sealing of dams and hydraulic structures with geomembranes, etc.
- innovative methods of repair
- use of roller compacted concrete (RCC)
- increasing spillway control with rubber dams, fusegates, etc.
- preservation of historic structures
- improved environmental management
- knowledge systems that collect and analyse asset data and support modernization decisions
- the large body of knowledge collected in a variety of guides prepared by agencies, learned societies and research institutes

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# 3
# CHAPTER 3: SCREENING

## 3.1 Introduction to the Screening Process

The screening process in this section uses an asset management approach to assess life extension needs and modernization opportunities. A more detailed description of the screening process used in this document is set out in Volume 1, Section 3 of these Guidelines.

Proceeding with the civil and other components (civil) screening process depends on prior or parallel steps. Screening is recommended if the results of plant screening in Volume 1, Chapter 3 clearly indicate a need to proceed with a further detailed screening of unit equipment and structures such as turbines (Volume 2, Chapter 3), protection and control (Volume 7, Chapter 3), generators (Volume 3, Chapter 3) or Auxiliary Mechanical and Electrical Systems (Volume 4/5, Chapter 3). Screening is also recommended if the hydro plant owner is considering an action plan driven by structural condition, ageing or failure to meet level of service requirements.

The civil screening procedure is a quick and easy process used to evaluate whether life extension and/or modernization should be pursued. Through this process, the user can assess the potential for life extension and/or modernization of the civil assets and the performance of detailed, costly studies or uneconomic alternatives can be avoided. A question and answer system is used, and special measurements or tests are not required.

The screening in Volume 6 is complementary, but at a greater level of detail, to that contained in Volume 1, in that it considers each piece civil and other plant component (as appropriate).

Civil and other Plant Components cover:

- Intakes
- Spillways
- Dams
- Powerhouses
- Water conveyances

Using this approach for each type of equipment, a determination can be made of what are the needs and opportunities for a particular unit/plant. Screening factors relating to needs could result in life extension activity. Screening factors relating to opportunities could result in

modernization activities. Needs are measured by Indicators of Dependability and Sustainability. Opportunities are measured by Indicators of Output and Flexibility.

Indicators are a qualitative assessment based on a review of existing and easily obtainable information. They are provided to stimulate discussion and information gathering. The results of screening questions are summarized in Table 3-1 and then used as input to Step 3.3 of the screening process in Volume 1.

## 3.2 Screening for Life Extension

The screening for life extension of civil and other plant components is primarily related to a high level assessment of the Indicators of Dependability and Sustainability. These are described below.

Following this section is an annex (Section 3.3) that is common to all equipment and structures and is contained in each technical volume of these Guidelines. This annex considers the proportional allocation of funds across each project to determine if any significant anomalies are apparent. If so, they are also considered a Life Extension Indicator.

A1 Indicators of Dependability

| | | |
|---|---|---|
| A1.1 | Condition | Knowledge of the condition of the civil works |
| A1.2 | Performance | Level of service measured by required performance |
| A1.3 | Operational Risk (Safety) | Outstanding, identified or perceived risks related to civil works |
| A1.4 | Costs | Assessment of maintenance costs and comparison with other projects and industry averages |

A2 Indicators of Sustainability

| | | |
|---|---|---|
| A2.1 | Environmental Issues | Possibility or likelihood that civil works could cause an environmental impact relating to operation of the plant and discharge of flows |
| A2.2 | Catastrophic Risk | Assessment of outstanding, identified or perceived risks that could pose a significant risk |

The intent of the needs assessment for civil works is to provide information on specific requirements for the structures and input to overall plant ratings and prioritization (Volume 1, Section 3).

### A1.1 Condition

Indicators of Condition for civil works at the screening level can be obtained from a variety of sources including:

- interviews with hydro plant maintenance staff as well as technical specialists
- review of data bases including computerized maintenance management system
- previous studies on condition assessment, including test results
- review of any recent change in operation of the civil works that would result in increased wear and tear.

Condition Indicators are based on questioning:

- Does the condition of this specific civil component significantly affect its performance? i.e. is there evidence of structural deterioration ?
- Is the expected remaining life of the civil works less than five years?
- Are there existing or expected changes in the use of this civil component that will result in increased degradation to its condition?
- Is there a lack of knowledge on the condition of any critical civil work?
- Are there any test results that indicate poor, or worse, condition?

If the answers to one or more of the above question is YES, this indicates that the condition of civil component is a driver for life extension. It is important to note that Indicators are a qualitative assessment of existing condition based on a review of existing and easily obtainable information. The information for the specific civil component is summarized in Table 3-1 and then used in Step 3.3 of the screening process in Volume 1.

### A1.2 Performance

Indicators of Performance for civil component at the screening level can be obtained from a number of sources including:

- Review of performance of civil works
- Measurements from monitoring equipment and instrumentation

Performance Indicators are based on questioning:

- Is the performance now significantly decreased compared to the civil works original performance? i.e. is there evidence of AAR activity?
- Is the performance now significantly lower than required levels? i.e. losses due to seepage from the dams and hydraulic structures.

If the answers to one or more of the above questions is YES, it identifies that performance is a driver for life extension needs. The information for the civil component is summarized in Table 3-1 and then used as input to Step 3.3 of the screening process in Volume 1.

### A1.3 Operational Risk

Indicators of Operational Risk for civil works at the screening level can be obtained from:

- interviews with plant operations/maintenance staff on their understanding of the risks to the civil works in terms of failure or damage and the risks to worker safety.
- existing studies such as Failure Modes and Effects Analysis (FMEA) or Reliability Centered Maintenance (RCM).
- assessment by an experienced engineer familiar with the possible risks related to operation of civil works and to hydro plant staff.

Operational Risk Indicators are based on questioning:

- Could something happen to the civil structures that could result in failure or significant degradation in performance?
- Is there a lack of knowledge on the potential vulnerability of any critical civil works?
- Could something happen to civil works that could potentially result in a life safety consideration?
- Could civil work activities i.e., refurbishment, replacement, renewal, etc. mitigation those risks/hazards?

If the answers to one or more of these questions is YES, this indicates that the perceived operational risks warrant further study to determine life extension needs. It is important to note that Indicators of operational risk will be qualitative only. Information will be collected, collated for all equipment, summarized in Table 3-1 and incorporated in Step 3.3 of Volume 1.

### A1.4 Cost

Indicators of Cost for civil works at the screening level can be obtained from:

- computerized maintenance management systems
- financial data bases
- previous studies on cost allocation between plants, civil works and other plant components.

This may need to be levelized over a period of 5 years , for example, to account for any extraordinary activities. Account should also be allowed for high costs not directly related to the structures, such as mobilization to remote areas.

Cost indicators are based on questioning:

- Does the cost for maintenance of civil works fall in line with costs at other plants as well as industry data bases and standards?
- Are the significant changes (increases) in the cost of maintenance from year to year?

If the answers to either of these questions is YES, it identifies whether the costs warrant further study to determine life extension needs. The Indicator of costs summarized in Table 3-1 are at a high level and can be used in conjunction with the Annex on cost allocations (Section 3.3).

### A2.1 Environmental Issues

Indicators of Environmental Issues from civil works are primarily related to activities or events that could jeopardize the continued operation of the plant. Most utilities have assessed risks related to impacts from operation of the plant and the discharge of flows.

Environmental Issues Indicators are based on questioning:

- Has an assessment been undertaken for the civil works which indicates unresolved issues to species or the environment?
- Has an assessment of the risks from spills of hazardous substances been undertaken and do issues remain unresolved?

If the answer to either of these questions is YES, it indicates that further study may be warranted to identify any life extension needs. These are summarized in Table 3-1, then used as input to Section 3 of Volume 1.

### A2.2 Catastrophic Risk

Indicators of Catastrophic Risk from civil works are primarily related to activities or events that could pose a significant dam safety risk.

Most utilities and dam owners have assessed the risks at their project to dams and other water retaining structures. These primarily relate to hazards from extreme events such as floods and earthquakes, but also fundamental vulnerabilities in the civil works themselves (i.e. inadequate design or construction methods).

Catastrophic Risk Indicators are based on questioning:

- Are there any water retaining structures that could pose a catastrophic risk, which have not been assessed as to their potential risk?
- Has any assessment of catastrophic risk indicated areas of potential vulnerability which have not been resolved?

If the answers to either of these questions is YES, further action is required immediately and this information needs to be summarized in Table 3-1, then used as input to Section 3 of Volume 1.

## 3.3 Annex to "Screening for Life Extension"

Generalized Cost Allocation Screening Criteria

This annex can be used to enhance some of the qualitative screening criteria for equipment and civil works found in Volumes 2 through 7. It is particularly relevant for the Indicators of Dependability as used in the assessment of life extension needs. The first step will be to consider the overall cost allocation (total maintenance, excluding capital) between Powerhouse, Dam and Generating Units.[1]

Industry averages for each range between the following allocations:

| | |
|---|---|
| Powerhouse | 40 - 50% |
| Dams | 20 - 30% |
| Units | 30 - 40% |

Where the total maintenance costs for each subcomponent exceed these industry average allocations, this may be an indicator of life extension.

If, for example, the allocation of dams exceed 30%, check for specific conditions such as the presence of a number of dams or a newly built, small powerplant.

While this method only considers proportional allocations, a more specific assessment of maintenance cost assessment at the screening level has been included for the entire plant in Step 3.3 of the Volume 1.

## 3.4 Screening for Improvement Potential (Modernization)

The screening for modernization of civil works is primarily related to increased capacity, energy and the range of products and is assessed through Indicators of Output and Flexibility. Any input from this section can be added to the more generalized assessment in Step 3.6 of Section 3 in Volume 1, to assist in improving the overall screening process.

**It is strongly suggested that screening for any civil works improvement not be undertaken in isolation from considerations of the entire powerplant and infrastructure needs and opportunities.**

---

[1] Information collected by BC Hydro for the purposes of cost allocation. The following is included under each category:
1. Powerhouse: structural, management and administration;
2. Dam: dam safety, dam maintenance;
3. Generating Units: equipment maintenance

The screening indicators for civil works are:

B1 Indicators of Output

| | | |
|---|---|---|
| B1.1 | Capacity | Means to increase hydraulic head |
| B1.2 | Efficiency | Assessment of the use of the water resource |
| B1.3 | Equipment | Comparison with modern technologies |

B2 Indicators of Flexibility

| | | |
|---|---|---|
| B2.1 | Range of Products | Capability of civil works to increase range of products |

B1.1 Capacity

Indications of Capacity improvements for operating equipment are particularly complex and can usually only be assessed on a site specific basis. Nevertheless, if there is a potential for a reasonable increase in hydraulic head across the units, due to civil works improvement, and where unit upgrades are being considered for other reasons, increases in unit output are not uncommon and may be justified economically.

Indicators to assess whether civil works improvement would potentially allow increases in capacity output are based on questioning :

- Is there the potential to increase hydraulic head across the units by 5% or more by increasing operating levels or reducing tailwater levels (i.e. incorporating flashboards or the like on the spillway)?
- Does the setting of any runner relative to lowered tailwater level permit an increase of power of at least 10%?

If the answer to either questions is YES, it indicates that potential exists for civil works improvement. This information will be summarized in Table 3-1, then used as input to Section 3 in Volume 1.

B1.2 Efficiency

Indicators of Efficiency improvements due to civil works relate to the increased use of the water resource. At the screening level information can be obtained from:

- Review of the use of the water resource compared with best practice at other utilties.
- Assessment of hydraulic losses, from the water retaining structures and conveyances.
- Review of the potential to increase reservoir storage (permanent and/or seasonal) as well as increase reservoir levels.

Efficiency Indicators are based on questioning:

- Are there ways that the water resource can be used more efficiently (i.e. flashboards for permanent or seasonal non-flood storage)?
- Are there significant hydraulic losses in the present operation of the civil works (i.e. seepage past structures, friction losses in conveyances).
- Are there any significant opportunities to provide off-stream storage and/or divert additional water using construction or changed operations of civil works?

If the answer to any of these question is YES, there is a potential for improvements due to civil works. This information will be summarized in Table 3-1 then used as input to Section 3 of Volume 1.

### B1.3 Equipment

Indicators of Equipment improvement as part of civil works relate to replacement of old, worn or out of date equipment and replacement by latest, cost effective technologies. At the screening level information can be obtained from.

- Review of all equipment associated with civil works relating to its conditions, performance, risk and suitability for its required purpose.
- Review of new and innovative technologies relating to improvement in equipment associated with civil works.

Equipment indicators are based on questioning:

- Does any of the equipment associated with civil works have condition, performance or risk related issues that could likely affect its required purpose?
- Do new and innovative technologies exist and have been proven economic and feasible for the equipment presently in place and associated with the civil works? (i.e. improved spillway control system).

If the answers to either of these questions is YES, this indicates the potential for improvements to the equipment associated with civil works. This information will be summarized in Table 3.1, then used as input to Section 3 of Volume 1.

### B2.1 Range of Products

Indicators of Flexibility in the range of products provided at any particular project are normally complex and can usually only be assessed on a site specific basis. Fundamentally, it is an assessment of whether the project, through the civil works, and associated equipment, can readily be adapted {flexible} to changed operating conditions and changes in demand for products and services.

Indicators relate both to the supply side; the changes that can reasonably be made to the range of products related to the project and specifically the civil works, and the demand side, the requirements of the end-users and market drivers and the willingness to pay.

At the screening level, information on indicators for the Range of Products can be obtained from:

- Assessment of the full range of products that could be made available at reasonable cost based on improvements to civil works
- Assessment of future needs of the end users and the market drivers for the range of products and the "willingness to pay" for these products.

Range of Product Indicators are based on questioning

- Would improvements to civil works result in a significant increase in the number and amount of products and services available for the end-user and the market place (i.e. recreation, irrigation, flood control, water supply)?
- Is there a price or other mechanism available to cover the costs of investment in civil works that would result in an increased range of products and services.

If the answers to both questions is YES, this indicates a potential for improvement. The information will be summarized in Table 3-1, then used as input to Section 3 of Volume 1.

**Table 3-1**
**Civil and Other Plant Components**
**Summary of Screening Indicators**

Project: _____
Civil Component Name: _____
Asset No.: _____
Prepared by: _____
Date: _____

| Is Life Extension Indicated by: | | | Is Modernization Indicated by: | | |
|---|---|---|---|---|---|
| Dependability | Yes | No | Output | Yes | No |
| - Condition | ❒ | ❒ | - Capacity | ❒ | ❒ |
| - Performance | ❒ | ❒ | - Efficiency | ❒ | ❒ |
| - Operational Risk | ❒ | ❒ | - Equipment | ❒ | ❒ |
| - Cost* | ❒ | ❒ | | | |
| Comments: | | | Comments: | | |
| Sustainability | Yes | No | Flexibility | Yes | No |
| - Environmental Issues | ❒ | ❒ | - Range of Products | ❒ | ❒ |
| - Catastrophic Risk | ❒ | ❒ | | | |
| Comments: | | | Comments: | | |

* including assessment of cost allocation criteria.

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# 4
# CHAPTER 4: LIFE EXTENSION AND MODERNIZATION PROCESS

## 4.1 Introduction

A thorough coverage of the life extension and modernization process for hydroplants is provided in Volume 1 of these guidelines, with technical aspects relating to hydropower equipment covered in Volumes 2 to 5 and 7.

A summary of the life extension and modernization process is provided in this Chapter, with special reference to civil works. However the ASCE Guides which are hyperlinked to this document, contain numerous case histories and other information which illustrates how life extension and modernization works have been undertaken at a variety of projects..

## 4.2 Life Extension

Evaluations of the performance and condition of the civil structures are key steps in the formulation of an LEM plan as described in Volume 1, Chapter 4 of these guidelines. Information gathered during the plant screening process (see Volume 1, Chapter 3) and the civil structure screening process (see Chapter 3 of this document) is used for the performance evaluation and condition assessment. The LEM process is iterative, and life extension activities are identified at this first stage. The evaluations summarized in this chapter rely primarily on information and knowledge about the civil structures or new information that is inexpensive to obtain. Ideally, at this stage of the evaluation, a reasonable assessment of structure condition can be made without the use of extensive testing and analysis. After the LEM plan is formulated and projects are more clearly defined, additional testing or studies may be justified, as described in Section 4.4, "Feasibility". Figure 4-1 is a flowchart that describes how activities contribute to the development of the LEM plan.

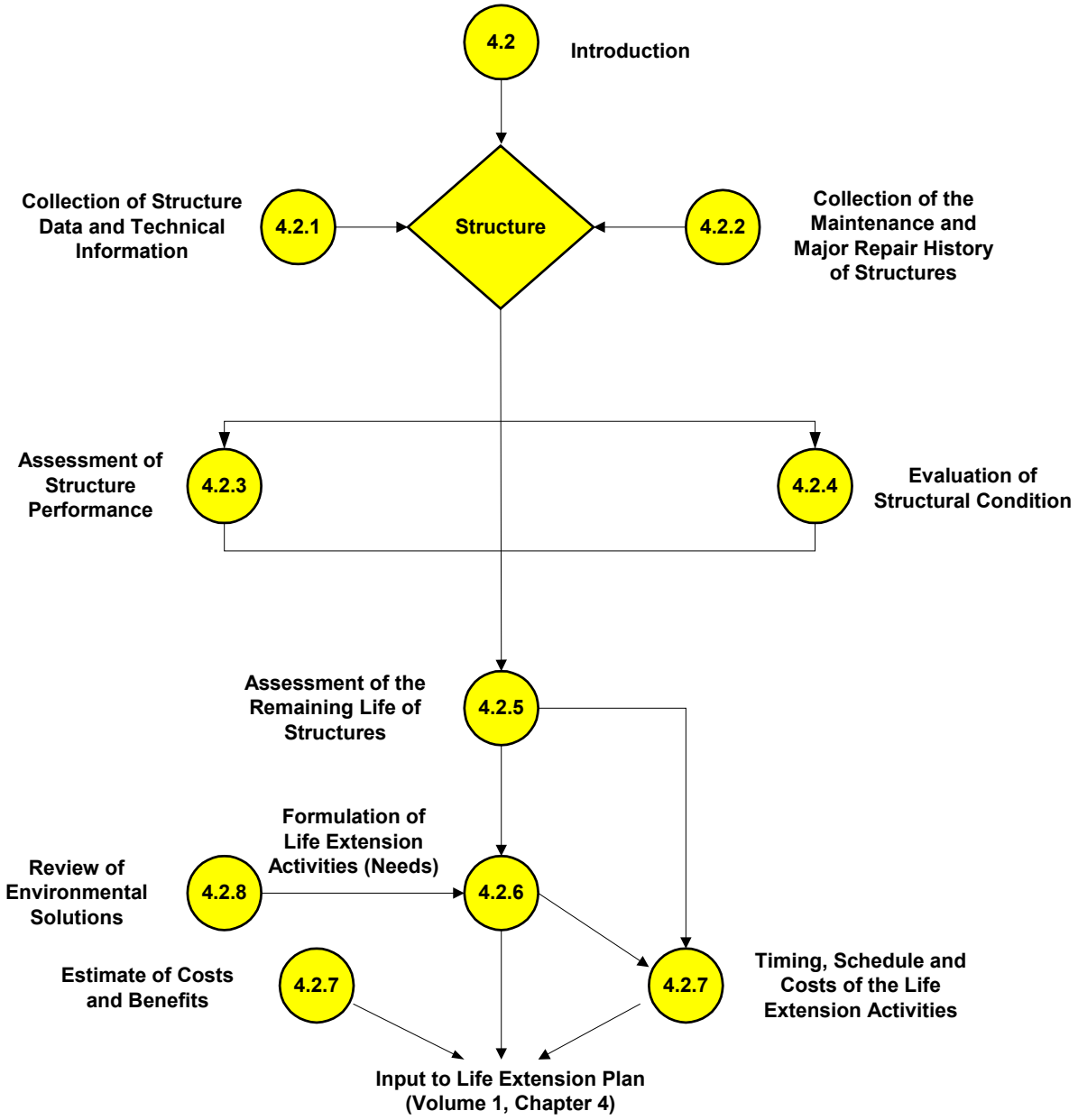


**Figure 4-1**
**Input of Civil Structural Data to Life Extension Plan**

Section 4.2 focuses on assessing the present performance and condition of the civil works and its remaining life and identifying activities that will extend life. Timing aspects of the identified life extension activities are nominated and a schedule of activities is formulated. The assembled information is used to develop tables of needs and opportunities in Volume 1, that are then used to develop the LEM plan.

To conduct the condition assessment for each structure and identify life extension activities, a Site Worksheet (Table 4-1) may be used , particularly for site visits, before inserting the information into the extensive tables in Volume 1. A worksheet is prepared for each civil structure based on the asset register assembled for the plant, which is described in Volume 1, Chapter 4.2. These worksheets ensure that all required information for the LEM projects are obtained. This section summarizes technical information to assist in completing the worksheet. A similar table for modernization opportunities is completed using Section 4.3 of this Volume.

**Table 4-1**
**Site Worksheet for Civil Structure Condition Assessment**
**Identification of Needs**

**Plant:** _____
**Civil Structure Name:** _____
**Unit No.:** _____
**Asset No.:** _____
**Prepared by:** _____ **Date:** _____

| **Equipment Data and Technical Information** | | **History of Maintenance and Major Repairs** |
|---|---|---|
| | | |
| **Performance and Operational Information** | | **Condition Assessment of Structures** |
| | | |
| **Risk Evaluation** | | **Assessment of Remaining Life** |
| | | |
| **Condition Rating (if available)** | **Repairability Rating** | **Environmental Issues** |
| | | |
| **Possible Life Extension Activities** | | **Timing and Costs of Life Extension Activities** |
| | | |

### 4.2.1 Civil Structure Data and Technical Information

**Table 4-1**

| | | |
|---|---|---|
| **Structural Data and Technical Information (Step 4-2, Volume 1)** | | History of Maintenance and Major Repairs |
| Performance and Operational Information | | Condition Assessment of Structures |
| Risk Evaluation | | Assessment of Remaining Life |
| Condition Rating(if available) | Repairability Rating | Environmental Issues |
| Possible Life Extension Activities | | Timing and Costs of Life Extension Activities |

**Desktop Review**

An assessment of the condition or performance of the plant's civil structures begins with the key data that describe the existing works. The technical data includes information on design and performance, original O&M instructions, and design changes. The value of this resource document will be recognized in successive stages of the review and ultimately in the actual design and implementation phase of LEM.

**Site Visit**

One purpose of a site visit is to verify, where possible, the information obtained from the desktop review. Another is to verify the history of maintenance and major repairs (Section 4.2.2) performance (Section 4.2.3) and condition (Section 4.2.4) through inspection and interviews with plant personnel. This includes verifying that the asset register is complete and checking nameplate data to ensure that all recorded technical information is correct. Chapter 4.3 of Volume 1 provides additional guidance on the purposes of the site visit.

Site personnel are often the best source of information, particularly when records of equipment and plant operation changes are unavailable or unorganized. Key personnel who assist in verifying technical data, operating characteristics, and maintenance /upgrade history include:

- Station O&M personnel, including trades supervisor
- Engineering support (technical)
- Previous project managers and retirees

### *4.2.2 History of Maintenance and Major Repairs*

**Table 4-1**

<table>
<tr><td colspan="2">Structure Data and Technical Information</td><td colspan="2">History of Maintenance and Major Repairs (Step 4-3, Volume 1)</td></tr>
<tr><td colspan="2">Performance and Operational Information</td><td colspan="2">Condition Assessment of Structures</td></tr>
<tr><td colspan="2">Risk Evaluation</td><td colspan="2">Assessment of Remaining Life</td></tr>
<tr><td>Condition Rating(if available)</td><td>Repairability Rating</td><td colspan="2">Environmental Issues</td></tr>
<tr><td colspan="2">Possible Life Extension Activities</td><td colspan="2">Timing and Costs of Life Extension Activities</td></tr>
</table>

A review of the history of maintenance and major repairs to the civil works, as well as future plans, is an important step in assessing condition and predicting remaining life. If available, the following reports should be obtained for further study to supplement the site visits.

- Annual station reports or year-end summaries for maintenance and capital projects to obtain summary information on changes to original design and performance.
- Station O&M summary records
- Historic cost data (capital and operating)
- Historic annual staff/personnel requirements
- O&M expenditures for the last 10 years

The information derived from these sources and guided by the following questionnaire and other searches and interviews should be documented, referencing sources by date and location. The questionnaire consists of the following:

- What is the trend in maintenance requirements (costs, hours and downtime) for the structures over the years? Is it increasing? Is it constant? This information should give an indication of condition. A chart of annual maintenance and capital costs separated into the major structures is valuable.
- Are there chronic problems with the structures and if yes, what are the problems?
- What major repairs have been done on the structures and did these repairs substantially improve their life expectancy.

### 4.2.3 Performance and Operational Information (Record)

**Table 4-1**

| | | |
|---|---|---|
| Structure Data and Technical Information | | History of Maintenance and Major Repairs |
| **Performance and Operational Information (Step 4-2, Volume 1)** | | Condition Assessment of Structures |
| Risk Evaluation | | Assessment of Remaining Life |
| Condition Rating(if available) | Repairability Rating | Environmental Issues |
| Possible Life Extension Activities | | Timing and Costs of Life Extension Activities |

The Desktop Review, Site Visit, and History of Maintenance and Major Repairs, complement the examination of the performance of the structures. The examination of operating records supports the condition assessment in Section 4.2.4.

### 4.2.4 Condition Assessment of Structures

**Table 4-1**

| | | |
|---|---|---|
| Structure Data and Technical Information | | History of Maintenance and Major Repairs |
| Performance and Operational Information | | **Condition Assessment of Structures (Step 4-3, Volume 1)** |
| Risk Evaluation | | Assessment of Remaining Life |
| Condition Rating(if available) | Repairability Rating | Environmental Issues |
| Possible Life Extension Activities | | Timing and Costs of Life Extension Activities |

Section 4.2.4 supports the technical information used to develop the LEM plan as described in Volume 1. Initial (screening) assessments might be revised after further, more detailed studies.

At this stage the owner operator will have the benefit of screening and performance reports (tables and summary support) for the structure as a whole. The technical data indicate the overall status of the structures and should allow identification of some of the obvious opportunities for repair or upgrade that might require limited effort to undertake.

Detailed instructions on condition and performance information that should be gathered and the criteria (indicators) that are useful for assessing equipment condition can be found in the following documents. From these, the information obtained on equipment condition can be fed into a condition rating process, if necessary, or used on its own.

- ASCE (1992) Guidelines for Rehabilitation of Civil Works of Hydroelectric Plants American Society of Civil Engineers, New York, NY.
- The REMR process, developed by the USACE, which has a condition Index Scale as a standard definition of condition. The complete REMR guidelines can be obtained from the USACE, and a list covering civil works is included in Appendix A of the ASCE Guides (Section 5.8).

### *4.2.5 Assessment of Remaining Life*

**Table 4-1**

<table>
<tr><td colspan="2">Structure Data and Technical Information</td><td colspan="2">History of Maintenance and Major Repairs</td></tr>
<tr><td colspan="2">Performance and Operational Information</td><td colspan="2">Condition Assessment of Structures</td></tr>
<tr><td colspan="2">Risk Evaluation</td><td colspan="2">Assessment of Remaining Life<br>(Step 4-8, Volume 1)</td></tr>
<tr><td>Condition Rating(if available)</td><td>Repairability Rating</td><td colspan="2">Environmental Issues</td></tr>
<tr><td colspan="2">Possible Life Extension Activities</td><td colspan="2">Timing and Costs of Life Extension Activities</td></tr>
</table>

The estimation of remaining life is the most subjective element of the condition assessment. The overall objective is to replace, rehabilitate or upgrade structures at the optimum point in their life cycle. The scheduling of these activities requires that the approximate year of any failure is predicted. Such predictions should be made by an experienced engineer, who has a thorough knowledge of the structure as well as access to industry statistics on its service life under specific operating conditions.

Optimum time in this context means the time beyond which the impacts of **not** intervening will be greater in the long run than the impacts of intervening now. In terms of risk cost, this is the time when the risk costs are minimized. Risk costs include the costs of structure replacement and the consequences of failure (such as lost energy, collateral damage and cost increases for construction or installation of new structures due to working in an "unplanned" outage situation).

Under the auspices of the CEA Technologies Inc., an interest group of energy companies from Canada, the United States, Sweden, Australia and New Zealand have undertaken "remaining life" studies for hydro power equipment and structures (penstocks). The results of this project have been used to develop replacement strategies for equipment and structures, and computer software tools to assist with the prediction of remaining life and scheduling of equipment replacement. Costs associated with equipment replacement decisions are included in the methodology used to arrive at optimal timing for structures replacement.

Frequently, condition is not the only driver for replacement and remaining service life is not a factor in the replacement decision. The real driver of rehabilitation or replacement can be upgrade opportunity for increased performance (that is, plant or system revenue) through increased power and efficiency.

A note should be made in the Condition Summary worksheet when "useful life" is the issue driving replacement rather than "remaining service life".

### 4.2.6 Life Extension Activities

**Table 4-1**

| | | |
|---|---|---|
| Structure Data and Technical Information | | History of Maintenance and Major Repairs |
| Performance and Operational Information | | Condition Assessment of Structures |
| Risk Evaluation | | Assessment of Remaining Life |
| Condition Rating(if available) | Repairability Rating | Environmental Issues |
| **Possible Life Extension Activities (Step 4-5, Volume 1)** | | Timing and Costs of Life Extension Activities |

The scope of projects for an LEM plan range from the rehabilitation of one or more components such as the penstocks or the gates to a complete powerplant replacement.

The decision to rehabilitate or replace a structure has an effect on the scheduling of other life extension activities. For example, if the decision is made to replace a structure in five years, then other typical life extension activities such as painting may be reduced in scope or eliminated altogether from the LEM Plan in the preceding years.

### 4.2.7 Timing, Schedule, and Cost of Activities

**Table 4-1**

| | | |
|---|---|---|
| Structure Data and Technical Information | | History of Maintenance and Major Repairs |
| Performance and Operational Information | | Condition Assessment of Structures |
| Risk Evaluation | | Assessment of Remaining Life |
| Condition Rating(if available) | Repairability Rating | Environmental Issues |
| Possible Life Extension Activities | | **Timing and Costs of Life Extension Activities (Step 4-8, Volume 1)** |

The condition assessment provides the early framework for an LEM Plan. Structure and other civil works activities have been identified and now need to be organized into a 20 year (or other planning horizon) plan. Before specific activities can be assigned to a particular year in the LEM Plan, certain policies and guidelines on the assignment of activities must be established. The following are some of the questions that must be answered:

- Is the general philosophy concerning LEM opportunities one of consolidation (that is, trying to do as much work as possible during an annual shutdown)? This would be the philosophy if lost revenue due to shutdowns was high and over-shadowed the capital requirements for the actual work.
- Are there limits on the capital available in any one year? This may limit the scope of work for a particular year even though there would be benefits to combining work activities instead of completing them over several years.

- Is there a preference in maintaining a constant level of annual expenditure and staffing (that is, spreading out LEM activities to avoid years of very high capital requirements and to level out staffing requirements)?

Once these questions have been resolved, the LEM activities can be scheduled over the required planning horizon on both technical and financial terms.

### *4.2.8 Environmental Issues*

**Table 4-1**

<table>
<tr><td colspan="2">Structure Data and Technical Information</td><td colspan="2">History of Maintenance and Major Repairs</td></tr>
<tr><td colspan="2">Performance and Operational Information</td><td colspan="2">Condition Assessment of Structures</td></tr>
<tr><td colspan="2">Risk Evaluation</td><td colspan="2">Assessment of Remaining Life</td></tr>
<tr><td>Condition Rating(if available)</td><td>Repairability Rating</td><td colspan="2">Environmental Issues (Step 4-6, Volume 1)</td></tr>
<tr><td colspan="2">Possible Life Extension Activities</td><td colspan="2">Timing and Costs of Life Extension Activities</td></tr>
</table>

Environmental issues surrounding hydroplants can be very complex, and a detailed explanation of all hydro plant environmental impacts is beyond the scope of these guidelines. However, in general they can be divided between:

- Project activities that can have an environmental impact
- The LEM projects that can be implemented to manage the environmental issues associated with civil works.

This subsection does not covers impacts associated with construction activities during implementation of the project. Guidance on management of environmental considerations during implementation are provided in Volume 1.

The International Organization for Standardization (ISO) Standard 14000 for implementing effective environmental management systems is an international standard designed for individual companies to set their own environmental goals and commitments to environmental policy. ISO 14000 guides the company to formulate a plan and to carry out a policy to identify significant activities that affect the environment in the production of a good or service. The company then trains personnel in environmental practices, and creates an internal audit review system to ensure the program is implemented and maintained.

## 4.3 Modernization: Potential for Improvements

Section 4.2 outlined a methodology to assess the performance and condition of civil structures and provides input to the life extension portion of the LEM plan. This section provides input to the modernization portion of the LEM plan. In addition, it provides a summary of information on assessing the upgrade opportunities that are available for structures in order to improve hydro plant performance beyond historical levels.

Figure 4-1 shows the contribution of this chapter to the identification and assessment of modernization opportunities for the entire plant, as documented in the LEM Plan.

During the condition assessment of the structures, life extension requirements are identified. When significant life extension work, in the form of rehabilitation or replacement is required, an informed decision needs to be made concerning whether modernization is warranted (the term *modernization* and its synonyms are defined in Chapter 1). Upgrading of structures is complex because modernization of one structure often has implications on other structures or plant equipment and the desired benefits may not be realized because of other plant limitations.

Volume 1, Appendix B of these guidelines provides a general discussion on how to identify modernization opportunities. Modernization opportunities are classified into the following main categories:

- Energy
- Portfolio services including capacity, storage, river system regulation
- Ancillary transmission services
- Operational flexibility
- Automation
- Other services

Chapter 3 of the ASCE Guides (Section 5.3) provides examples of innovative approaches to modernization of civil works. Some examples include increasing or controlling reservoir water levels with flashboards, rubber dams and fusegates, as well as reducing hydraulic losses in water conveyance structures.

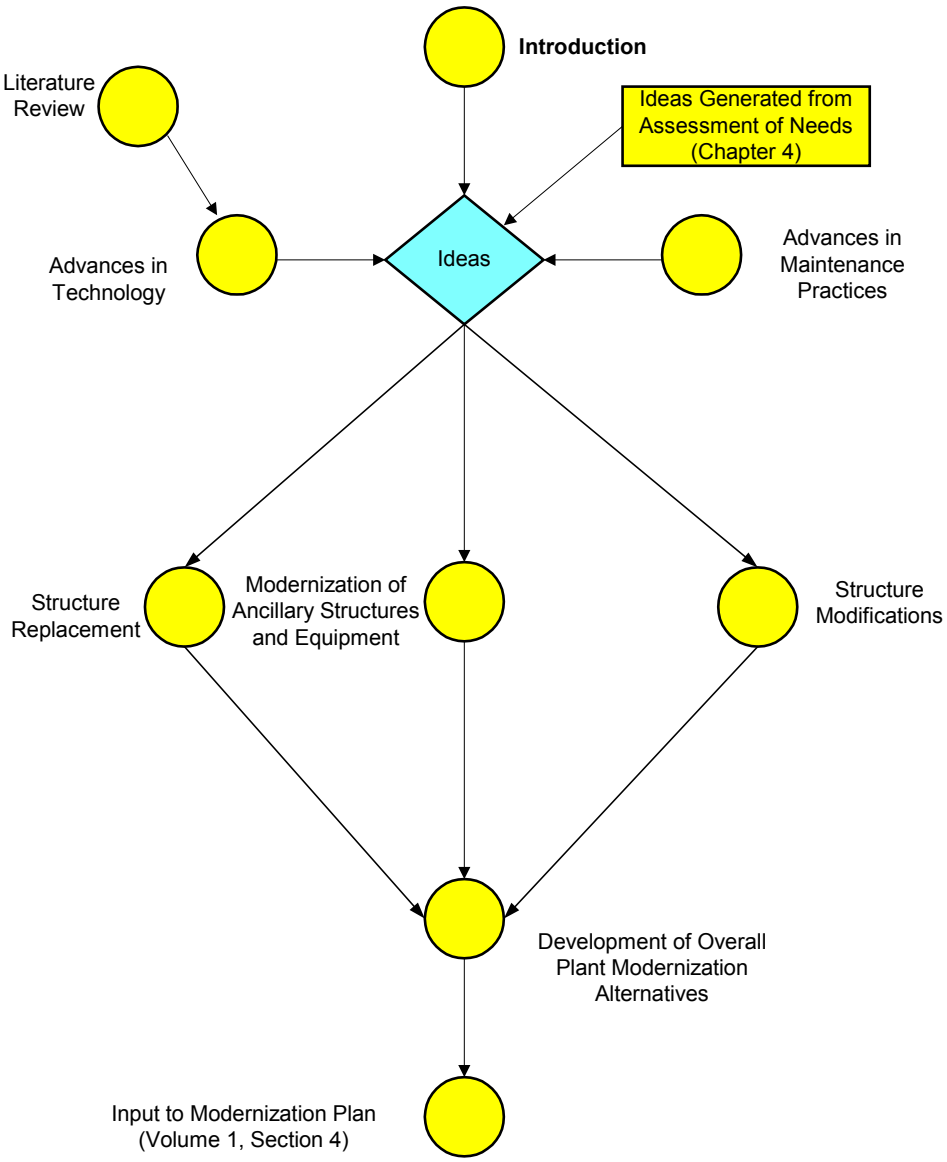


**Figure 4-2**
**Potential for Improvements Process**

The *pro forma* "Structures Modernization Opportunities" worksheet (see Table 4-2), sometimes referred to as the *site worksheet*, can be used for recording modernization opportunities.

**Table 4-2**
**Site Worksheet for Structures Modernization Opportunities**

**Plant:** _____
**Structure Name:** _____
**Unit No.:** _____
**Asset No.:** _____
**Prepared by:** _____ Date:_____

| **Modernization Opportunities** | **Benefits of Modernization** |
|---|---|
| | Structure: |
| **Further Studies Required** | |
| | Overall Plant: |
| **Impacts of Modernization on Other Structures and Equipment** | **Structures and Equipment that Limit Modernization** |
| | |
| **Timing & Costs of Modernization** | **Risk Evaluation of Modernization** |
| | |
| **Modernization Opportunities Selected for Input into LEM** | |
| | |

## 4.4 Feasibility: Optimization of Alternatives

The hydroplant owner will either have an experienced and knowledgeable engineering staff, or will select a suitable consultant for the feasibility stage analysis of LEM projects. Consequently this section will outline the process with limited coverage of technical details.

Sections 4.2 and 4.3 contributed to the formulation of LEM plan with the information obtained largely from existing operational and test data, reports, site visits and inspections.

At the completion of the LEM plan, the most favourable activities will be selected for more detailed study at the feasibility level. The projects identified in the selected LEM plan(s) may require more accurate, up to date information to verify the technical feasibility. This can be achieved by:

- Identifying and optimizing alternatives
- Selecting the best alternative
- preparing a feasibility level design and cost estimate of the selected alternative

- undertaking a sensitivity analysis

This section summarizes the process for obtaining more detailed information for the feasibility study. This is shown graphically on Figure 4-3.

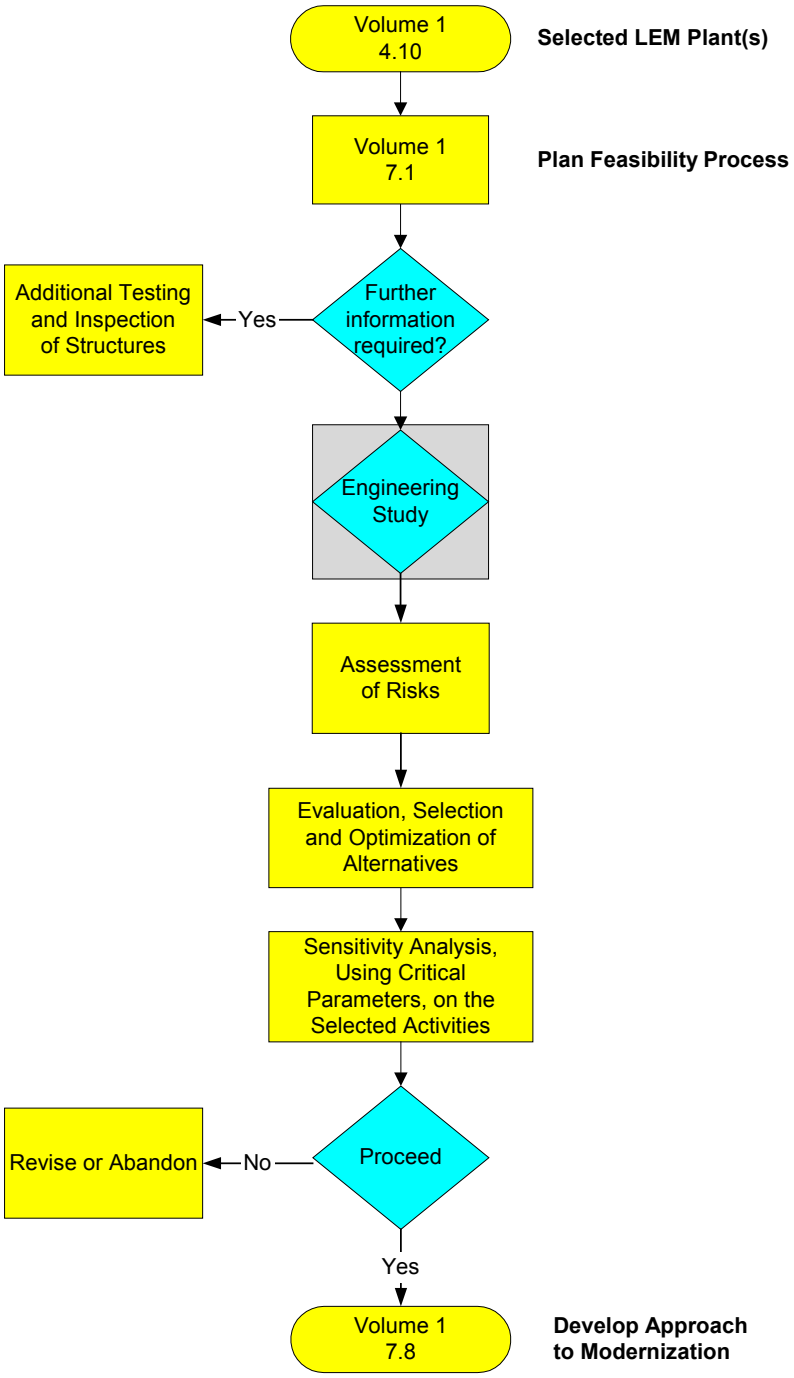


**Figure 4-3**
**Optimization of Alternatives Flowchart**

### 4.4.1 Additional Testing and Inspection of Civil Works

The level of testing and inspection normally gathered for development of the LEM is based either on the use of available data and information, or from straightforward, low cost activities.

At the feasibility level, it is often necessary to undertake more comprehensive testing and inspection focused specifically on the structure, its operating environment and mode, and the results of previous work.

Examples include:

- Testing of wall thickness of steel conduits and gates
- Testing of condition of coating for penstocks, etc.
- Inspection and testing of concrete where AAR is suspected
- Testing of water quality from dam seepage
- Inspections of foundations for civil works

### 4.4.2 Engineering Studies

The LEM planning process outlined in Sections 4.2 and 4.3 is iterative and designed to minimize expenditures. This avoids large expenditures on studies that should not be conducted until it is shown that the proposed project has merit.

During feasibility engineering studies are used to bring the required information together to make rational decisions on the feasibility of specific activities. The process can include:

- Assessment of previously gathered information
- Assessment of results of inspection and tests
- Analysis of impacts of proposed modernization on overall plant
- Buildability analysis
- Value engineering
- Improvements in assessment of costs
- Improvements in assessment of benefits
- Selection of best modernization plan

### 4.4.3 Risk Considerations

Risk management is the ability to balance risks with potential gains by making wise decisions. The process outlined in these Guidelines is the first step in reducing the owner's risk (Chapter 4, Volume 1).

As part of the feasibility study process, the risks associated with each option should be assessed. Each risk, along with the potential mitigation available, can be identified. Risk areas to be considered include:

| **Area** | **Risk** |
|---|---|
| Technical and technological | • Proposed modernization activity is not feasible<br>• New structure does not meet performance levels<br>• Technology changes make modernization obsolete<br>• Inadequate assessment of condition<br>• Incorrect designs and inadequate quality assurance<br>• Once work is initiated, more needed work is identified |
| Construction | • Inadequate procurement process<br>• Delayed schedule, longer outages<br>• Consequential damage<br>• Contractor unfamiliar with specific work<br>• Poor estimates of cost leading to overruns<br>• Worker safety |
| Environmental | • Disposal of used materials<br>• Pollution and spills |
| Operating | • New operation does not achieve expected gains |

The user should examine all of these work areas with particular regard to the structural activities proposed.

### *4.4.4 Evaluation, Selection, and Optimization of Modernization Plan*

Modernization activities (opportunities) are identified, assessed, and screened as part of this chapter and Volume 1, Chapter 4. This provides an LEM plan for civil works in the context of the overall plant. The next stage in the process is to identify and evaluate alternatives in detail and to select the best. This may require additional testing and inspection of structures, engineering studies and the identification and evaluation of the risks associated with each alternative, activity or project. A modernization plan can then be selected and optimized before undergoing a final sensitivity analysis.

### *4.4.5 Sensitivity Analysis Using Critical Parameters of Costs and Benefits*

An integral part of the project analysis is conducting a sensitivity analysis on the selected modernization plan using parameters that are critical to the selected modernization project's success. These parameters can be separated into two categories: costs and benefits.

### *Costs*

Cost parameters to be assessed for sensitivity analysis include:

- Engineering costs
- Licensing costs
- Construction costs

Engineering Costs

Engineering costs include those associated with the detailed engineering design following the decision to proceed. They would also include any significant testing, site investigations and computerized evaluation that may be required.

Licensing Costs

Licensing costs include all those associated with the relicensing process applicable to the project under consideration. This can be a particular concern due to the open-ended nature of the process. Volume 1, Chapter 6 contains details of the relicensing process.

Construction Costs

Construction costs include all costs associated with the construction process. These can include costs associated with:

- Claims for extras by the contractor(s)
- Consequential costs from the contractor's claims, for example, other contractor claims, legal costs, and administration costs
- Delays to the completion of the project that could incur costs to the owner, for example, additional administration costs and cost of additional lost production
- Escalation (if the project is over an extended period of time)
- Interest rate movements
- Exchange rate movements

### *Benefits*

Benefit parameters to be assessed for a sensitivity analysis include:

- Value of energy
- Fuel cost

Value of Energy

The expected value of energy in the future is predicted by the owner, but a sensitivity analysis of the prediction might be required. It is difficult to specify a percentage range to assess but, in an open market, this could be high on a short-term basis. Each owner will have their own methodology.

Fuel Cost

Fuel, which in the case of hydro plants is water, normally has costs. These are frequently related to water usage, storage, or capacity costs. The sensitivity analysis considers possible changes (increases) in water usage fees and the shared users of the resource.

## 4.5 Project Definition and Implementation

Previous sections have provided information for the user to identify, evaluate, and select an appropriate LEM plan for civil works and confirm the feasibility of selected activities. This section assists the user by summarizing a general plan for implementing the work. As noted previously, it is assumed that the owner has engineering staff familiar with project management or has retained a consultant to oversee implementation of the work.

Figure 4-4 outlines the steps involved in preparing proposed LEM activities for implementation.

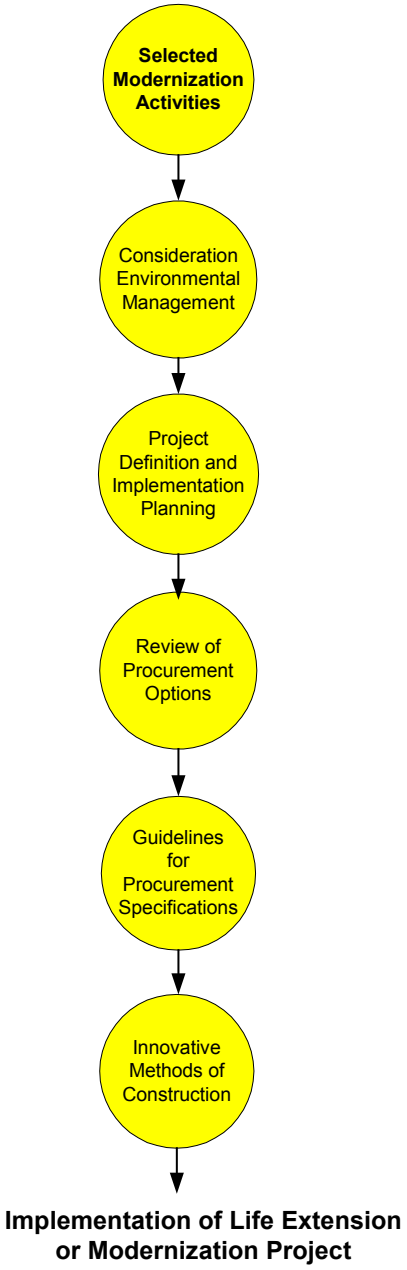
Selected Modernization Activities
Consideration Environmental Management
Project Definition and Implementation Planning
Review of Procurement Options
Guidelines for Procurement Specifications
Innovative Methods of Construction
Implementation of Life Extension or Modernization Project

**Figure 4-4**
**Implementation Process**

### *4.5.1 Environmental Management Considerations*

Environmental issues discussed previously are centered on the possible environmental impacts from the civil works. At the implementation stage, the focus turns towards licensing approvals, the schedule to achieve them, and management of environmental matters on site during

construction. In addition, the measurement of environmental improvements from the project is a necessary follow-up task. This subject is described extensively in Volume 1, Chapter 6.

### 4.5.2 Project Definition and Implementation Planning

After the LEM process has moved through its investigation and decision-making phases, and the decision is made to proceed with a particular project, the work moves to the definition and implementation phase. This consists of defining the project and implementing the work. Activities include:

- Project management
- Detail design engineering
- Procurement
- Construction
- Construction management
- Testing and commissioning
- Documentation

Volume 1, Chapter 8 describes the project definition and implementation portion of the process in detail. Each hydroplant owner will normally have procedures in place for these activities. Accordingly, the information presented is general in nature and intended to prompt some consideration of alternatives that may not currently be considered.

### 4.5.3 Procurement Options

Procurement options are covered extensively in Volume 1 of these guidelines. The options available usually depend on the procurement philosophy of the owner. Each new project, however, provides an opportunity for the owner to revisit the options available to complete the project.

### 4.5.4 Technical Specifications and Legal Documents

Specifications, along with the contracts they are associated with, are the means of sharing risk between the owner and the contractor. Therefore, it is important to ensure that the specification is designed to correctly define risk and to minimize the risk payment that the contractor can seek from the owner. The more unknowns built into the specification, the more risk cost the contractor may build into the price or attempt to recover through change orders.

Most owners will have a procurement policy with standard documentation in place and further information on contracting processes can be found in Volume 1 of these Guidelines and in Chapter 8 of the other technical volumes.

### 4.5.5 Innovative Methods of Construction

Innovative methods of construction usually develop from an unusual problem that must be solved in the planning stages of a project. Hydropower magazines and journals often present case studies of interesting construction projects that are good sources for keeping abreast of new construction techniques that reduce costs and time. Some examples take directly from published case studies that highlight interesting approaches to construction can be found in Chapter 3 of the ASCE Guidelines (Section 5.3).

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# 5
# CHAPTER 5: ALIGNING EPRI GUIDE, VOLUME 6, WITH ASCE GUIDE

## 5.1 Introduction

The development of Volume 6 of these Guidelines has already been acknowledged as a joint approach with the ASCE Guides (Section 1.3). This section will first describe how each set of Guides has been developed and then indicate how the reader can use them together.

### *5.1.1 EPRI Guidelines*

The EPRI Guidelines for Life Extension and Modernization of Hydroplants is a 7 volume set built around an asset management approach to the entire hydroplant (from water to wire).

Volume 1 (EPRI, 1999) outlines the overall approach to evaluating a powerplant, with Volume 2 to 7 (EPRI 2000 to 2004) covering technical aspects of the major equipment, systems and components.

Volume 6, the last volume to be completed, covers Civil and Other Plant Components of the hydroplant. In keeping with the asset management approach, it considers these components as integral parts of the hydroplant. Life extension activities are necessary to maintain performance whereas modernization is considered for improvements. These concepts are covered in Chapter 1 of Volume 1.

### *5.1.2 ASCE Guidelines*

The ASCE Guidelines for Life Extension and Upgrade of Civil Works for Hydroelectric Facilities (ASCE, 2005) is a single volume covering the civil works that are the principal project features of hydroelectric projects.

The ASCE Guidelines are divided into seven chapters. The first chapter introduces the guidelines and summarizes their intent and scope. Planning and Evaluation, Chapter 2, describes the process of extending service life and improving performance, determining project information that contribute to the basis for decision-making and putting it all together into a condition assessment. Innovative Technologies, Chapter 3, outline ways to extend the life and modernize civil components by the use of innovative technology. Chapter 4 - Structures, Chapter 5 - Water Conveyances, and Chapter 6 - Water Control Devices are the essence of the Guidelines. Organized by principal project feature, these chapters describe common problems,

their causes, some typical solutions, and real-world examples of what has worked and what hasn't worked. The reader is informed about problems that already have been solved with the objective of learning from the experience of others thereby eliminating some of the trial and error associated with the steep portion of the "learning curve". Other Considerations, Chapter 7, discusses other important project features that should be considered during a life extension or upgrade. This includes topics such as instrumentation, flood proofing, oil containment, and project security.

References and resources are contained in three separate locations of the ASCE Guidelines. A list of technical references, organized by principal project feature, is included at the end of each chapter. References representing some of the "Best Collective Knowledge" of the committee for each of the features are summarized at the end of the section covering each feature. Other important resource documents can be found in Appendix A. Notations in parentheses in the text refer to the technical references at the end of each chapter.

The knowledge base from which the ASCE Guidelines are derived is a long and rich history of experience in making things last longer and work better. In a previous document prepared by an ASCE Task committee (ASCE, 1992)[1], the focus was on describing the methods of assessing the condition of the civil works of hydroelectric plants and to outline some of the procedures available for civil works rehabilitation and repair.

The current ASCE guideline is intended to go a bit further and provide project owners, operators, constructors, and practising professionals with techniques and applications that have been successful in extending service life and improving performance of hydroelectric civil works. The intended audiences are the practising engineers who wish to build on the experiences of others, owners and operators, regulatory agencies, and non-governmental agencies.

### *5.1.3 How to Link the EPRI and ASCE Guides*

The primary medium for the EPRI Guide is on CD Rom as a Pdf file. The ASCE Guide is also included on this CD Rom as a Pdf file.

Sections 5.2 to 5.7 of this chapter correspond to chapters on the same subject matter in the ASCE Guidelines. As the reader follows the EPRI Guideline process, both cross references and hyperlinks will be made from this chapter to corresponding sections and case histories in the ASCE document.

## 5.2 Planning and Evaluation

The planning and evaluation of civil and other plant components, leading to development of a Life Extension and Modernization Plan has been described extensively in Chapter 4 and Volume 1 of these EPRI Guidelines.

Chapter 2 of the ASCE Guidelines include subject matter covering:

Planning and Evaluation Process

Identify Need for Project

Assemble Data and Information

Identify Parties Involved

Plan and Evaluate Alternatives

Selection of Preferred Course of Action

Moving forward with a Life Extension or Upgrade Project

Technical References/Bibliography

## 5.3 Innovative Technologies

Chapter 3 of the ASCE Guidelines is a review of innovative technologies and processes that have been used to extend the life or upgrade many civil aspects of a hydropower development.

Table 5-1 shows the coverage of Chapter 3 in the seven key areas of interest, as well as the structures to which these innovative technologies and processes may apply.

**Table 5-1**
**Innovative Technologies for Life Extension and Upgrade**

| Section/Activity | Solutions | Civil Works Features |
|---|---|---|
| 3.2 Surveillance Techniques | • Underwater surveillance and remotely operated vehicles<br>• Automation of instrumentation and monitoring<br>• Flow measurement | Tunnels<br>Intakes<br>Dams<br>Penstocks |
| 3.3 Assessment Techniques | • Condition assessment<br>• Business risk assessment<br>• Testing | Spillways<br>Gates<br>Penstocks<br>Hoists |
| 3.4 Performance Analysis | • Alkali aggregate reaction (AAR)<br>• Reduction of hydraulic losses<br>• Sealing dams and hydraulic structures | Dams<br>Spillways<br>Tunnels<br>Reservoirs<br>Intakes |
| 3.5 Life Extension Methods | • Underwater repairs<br>• Construction methods<br>• Relining and repairing water passages<br>• Repairing concrete and masonry dams | Tailrace<br>Tunnels<br>Intakes<br>Penstocks<br>Dams |

| Section/Activity | Solutions | Civil Works Features |
|---|---|---|
| | • Protective coatings<br>• Rehabilitation of gates<br>• Use of roller compacted concrete (RCC) | Gates |
| 3.6 Modernization (Upgrade) Methods | • Increasing operating head | Flashboards<br>Rubber dams |
| 3.7 Environmental Considerations | • Preserving historical structures<br>• Removal of hazardous materials<br>• Maintaining habitat<br>• Reservoir ice<br>• Reservoir debris<br>• Fish passage<br>• Reducing noise<br>• Water quality | Powerhouses<br>Intakes<br>Trashracks<br>Fish Passage<br>Spillways<br>Tailraces |
| 3.8 Management & Knowledge Systems | • Management approaches<br>• Decision support<br>• Guides and Standards | All components |

## 5.4 Civil Structures

Chapter 4 of the ASCE Guidelines introduces the perspective of how real problems associated with civil structures are identified, defined and implemented to extend the life or upgrade specific civil features of a hydroelectric project or dam.

The definition of life extension and upgrade as used in the ASCE Guidelines is a follows:

Service Life Extension - Activity that extends the life of the feature beyond that which would be expected with normal maintenance (make it last longer).

Upgrade - Activity that improves performance of the feature beyond the current performance (make it work better). Exchange of a system or component with a similar or different system may not necessarily be considered an upgrade.

Chapter 4 Structures, Techniques and Applications is organized by principal project feature namely intakes, dams, spillways and reservoirs, powerhouses, fish passage, trash racks and trash rakes. This chapter describes examples and solutions as a way to illustrate techniques for improving the performance or extending the service life of structures for hydroelectric plants. Also provided in Chapter 4 is general broad-based information or "rules of thumb" to allow the reader to assess if or when a feature has reached the end of its service life, or if the feature warrants or is capable of improvements to its performance.

Introduction to each feature

The format used in Chapter 4 starts with descriptions of the function of specific types of civil features, their problems and limitations, and possible corrective measures and alternative solutions for life extension or upgrade. Depending on the feature being described, not all sub-sections will present the full range of information.

**Function :**

A brief description of the function or purpose of the feature is provided. Some civil features may have multiple uses as part of the hydroelectric project. Depending on the actual use and functions of the structure, its expected service life and opportunities for improvement can be determined.

**Problems:**

Typical problems and limitations (multiple if applicable) and the (root) causes are identified. If the civil feature has an operating system, a description of the limitations of the system is provided. Some problems are presented as a simple list and others are described in detail. General, broad-based "rules of thumb" regarding the service life, design or operational performance of a structure are provided as applicable. These are intended to provide guidance as to whether a structure has reached the end of its life, or the feature and its function could be improved.

**Corrective Measures:**

Options are identified that have been used (or considered for use) to rectify the problems identified. For solutions with multiple alternatives, the pros and cons of the alternatives are discussed. However, the solution identified may be site specific, and may not be applicable to all similar problems.

**Opportunities:**

Possible opportunities (additional benefits) are identified for upgrading (improving) the civil feature beyond that associated with just addressing a problem or limitation of service life.

Table 5-2 is a summary of issues associated with the function of each type of structure which is described in Chapter 4 of the ASCE Guides and the corrective measures, techniques and applications that have been covered in the text.

Case Histories

Following description of each structure, detailed example(s) are provided to describe typical solutions that have been used to address "real life" problems associated with that type of feature. In some examples the solutions may have extended the service life of a structure, improved its performance, or resulted in both an extension of service life and improvement of performance.

Each case history is structured to provide the following information:

- Background to the project and the function of the civil feature (background)
- Problems and causes (problem)
- Corrective measures and selected alternative (solution)
- Results of the project, opportunities and benefits (results)

Table 5-2 is also an index to the case histories given in the ASCE Guides for each structure. This index identifies the project from which the example is taken, the problem, solution and reference for further information.

References

There are three methods used in each Chapter to support the body of knowledge presented by the use of external resources.

- Collective Knowledge
- Technical References/Bibliography
- General Resources

The Best Collective Knowledge is a collection of references that supports the general descriptions of each structure, its function, challenges, solution and results. The references are located at the end of each section to which they are pertinent.

Technical References/Bibliography are specifically identified in the text of these guides, designated by name and date (i.e. ASCE 1995) with the full reference at the end of each chapter.

General Resources include any background resource that is deemed to have value for broader reference and additional reading. It includes learned societies and government agencies as well as manufacturing and commercial organizations. The list may be found in Appendix A of the ASCE document.

**Table 5-2**
**Summary of Issues, Techniques and Applications**

| Section | Title | Issue Covered* | Applications / Opportunities | Case History |
|---|---|---|---|---|
| 4.1 | Intakes | • Inadequate original design<br>• Change in performance criteria<br>• Deterioration of project components<br>• Hydraulic performance - head loss, approach velocities, vortices, model configurations, velocities, vortices, uneven distributions and levels<br>• O&M difficulties; rock trap cleanout, debris, sheet and frazil ice, sediment<br>• Downstream environmental issues - dissolved oxygen, water temperature | • Vortex suppression to improve performance<br>• Intake channel modifications to improve flow characteristics<br>• Multi-level intake towers for water temperature control<br>• Guide walls and guide vanes<br>• Sluicing of debris, ice and sediment<br>• Head loss reductions, hydraulic improvements and capacities for increased generation | 1. High Cost of Intake Operation and Maintenance<br>2. Increased Hydraulic Capacity<br>3. Hydraulic Approach Modifications<br>4. Control of Water Temperature<br>5. Seismic Upgrade of Low Level Outlet |
| 4.2 | Dams Spillways and Reservoirs | • Inadequate original design<br>• Change in performance criteria - adequacy of capacity and seismic design<br>• Deterioration of project and material components<br>• Structural integrity and stability issues<br>• Performance of flow surfaces<br>• Non-functioning or non-existent drains<br>• Alkali-aggregate reactivity (for concrete structures)<br>• Leakage - through joints and membranes<br>• Loss of material - timber crib dams<br>• Foundation uplift<br>• Hydraulic fill dams - liquefaction<br>• Lack of flood proofing<br>• Erosion of channels<br>• Seepage through or beneath earth fill dam<br>• Foundation drain cleaning<br>• Buttressing to improve seismic resistance<br>• Foundation grouting to reduce seepage | • Alkali-aggregate reactivity remediation, slot cutting<br>• Increase spillway discharge via structural improvements; new or additional spillway, raise dam or add crest wall<br>• Provide overtopping protection with grass, geotextiles, mattresses, gabions, riprap, concrete and concrete blocks, RCC and soil cement<br>• Lower or lengthening spillway crest<br>• Providing aeration to reduce cavitation on surfaces<br>• Changing spillway operating characteristics to extend life<br>• Air bubbler system to reduce ice loading<br>• Applying corrosion repair materials<br>• Epoxy injection for cracking<br>• Controlling spillway crest level with inflatable system<br>• Ultrasonic testing to locate voids in spillway slab<br>• RCC surfacing of spillway<br>• Anchoring to improve stability to meet design criteria<br>• RCC mass for stability<br>• Drains and grouting to reduce uplift<br>• Armoring of spillway channel | **Concrete Dams and Spillways**<br>1. Spillway Surface Deterioration<br>2. Dam Instability due to Flood Loading<br>3. Dam Instability due to Ice Loading<br>4. Insufficient Spillway Capacity<br>5. Inadequate Seismic Stability & Spillway Capacity<br>6. Erosion of Unlined Discharge Channel<br>7. Concrete Deterioration (Alkali-Aggregate Reactivity)<br>8. Instability (High Uplift Pressures)<br>9. Insufficient Spillway Capacity and Stability<br>10. Concrete Deterioration and Insufficient Dam Stability<br>11. Soluble Soils & Embankment Dam Failure<br>12. Alkali-Aggregate Reactivity<br>13. Alkali-Aggregate Reactivity<br>14. Foundation Leakage<br>15. Insufficient Spillway Capacity and Seismic Instability |

| Section | Title | Issue Covered* | Applications / Opportunities | Case History |
|---|---|---|---|---|
| | | | • Early notification systems for major flood events<br>• Relining and repair with geomembranes<br>• Sheet pile cutoffs<br>• Toe berms | 16. Flooding of Drainage Gallery and Insufficient Stability<br><br>**Embankment Dams**<br>1. Foundation Liquefaction<br>2. Toe Erosion at Outlet Works<br>3. Insufficient Spillway Capacity and Seepage<br>4. Insufficient Spillway Capacity<br>5. Foundation Liquefaction<br>6. High Underseepage Gradients<br>7. Seismic Instability<br><br>**Timber and Masonry**<br>1. Timber Crib Dam Deterioration<br>2. Masonry Dam Inadequate Stability & Spillway Capacity<br>3. Timber Crib Dam Deterioration<br><br>**Reservoirs**<br>1. Flood Design Criteria Change<br>2. Reservoir Liner Rehabilitation |
| 4.3 | Powerhouse | • Inadequate original design<br>• Change in performance criteria<br>• Foundation stability: settlement, heave<br>• Structural stability: seismic, hydraulic<br>• Structural damage: cracks, aging, poor maintenance, freeze-thaw, alkali-aggregate reactivity<br>• Seepage into powerhouse<br>• Roof damage: aging, poor maintenance<br>• Damage to water passageway: corrosion, cavitation, vibration<br>• Deterioration of project components | • Post tensioned anchors<br>• Pressure relief wells to drain foundations<br>• Waterproof coating of water passage wall to reduce seepage<br>• Powerhouse bridge crane and rail support upgrades<br>• Reduce maintenance costs<br>• Operating procedure improvements for civil works monitoring<br>• Civil works modifications to accommodate new equipment or equipment damaged by alkali-aggregate reactivity | 1. Deteriorated Concrete Spiral Case<br>2. Powerhouse Instability (Flood Loads)<br>3. Powerhouse Instability (Uplift Pressures)<br>4. Life Extension Study<br>5. Antiquated Bridge Crane<br>6. Deteriorated Supports and Antiquated Bridge Crane |

| Section | Title | Issue Covered* | Applications / Opportunities | Case History |
|---|---|---|---|---|
| 4.4 | Fish Passage | • O&M of fish passages<br>• Upstream and downstream passage<br>• Downstream passage increased predation<br>• Injury/mortality, increased predation<br>• Habitat alteration | • Transportation<br>• Screens<br>• Structural guidance<br>• Behavioural devices<br>• Turbine passage<br>• Fish pump exits<br>• Spillway releases<br>• Fish ladder<br>• Fish lifts<br>• Trap and haul<br>• Fish pumps<br>• Attraction flow<br>• Fishways | |
| 4.5 | Trash Racks | • Corrosion<br>• Inadequate design<br>• Structural damage and deterioration'<br>• Frazil and anchor ice<br>• Hydraulic loading<br>• Vibration<br>• Zebra Mussels | • Reduce head loss for increased generation<br>• Reducing maintenance costs for trash raking<br>• Excluding fish and eels<br>• Reduce approach velocities<br>• Corrosion resistant racks and coatings | 1. Deteriorated Steel Trash Racks<br>2. Temporary Trash Rack Repair<br>3. Trash Rack Failure Due to Inadequate Design<br>4. Blockage by Ice and Zebra Mussels<br>5. Trashrack Failure Due to Inadequate Design (Pump Turbines) |
| 4.6 | Trash Rakes | • Maintenance issues: damaged rake, worn out, alignment, damaged mechanical parts<br>• Reduced efficiency or generation and rake performance<br>• Personnel safety<br>• Inadequate lifting or sluicing capacity<br>• Need to dispose of large quantities of trash<br>• Increasing cost for debris removal | • Reduce O&M costs - automated operation<br>• Reduce head loss for improvement in generation<br>• Improved safety of personnel<br>• Prevent tripping due to differential head losses | 1. Debris Handling<br>2. Antiquated Trash Rake<br>3. Debris Handling |

* *Three key issues are common to all structures, namely; inadequate original design, change in performance criteria and deterioration of project components.*

## 5.5 Water Conveyances

Chapter 5 of the ASCE Guidelines introduces the perspective of how real problems associated with water conveyance features are identified, defined and implemented to extend the life or upgrade a hydroelectric project or dam.

The definition of life extension and upgrade as used in these guidelines is as follows:

Service Life Extension - Activity that extends the life of the civil feature beyond that which would be expected with normal maintenance (make it last longer).

Upgrade - Activity that improves performance of the civil feature beyond the current performance (make it work better). Exchange of a system or component with a similar or different system may not necessarily be considered an upgrade.

Chapter 5 Water Conveyance Structures, Techniques and Applications is organized by principal project feature, namely intake canals, flumes and forebay, tunnels, shafts and underground openings, penstocks and tailraces. This chapter describes examples and solutions as a way to illustrate techniques for improving the performance or extending the service life of civil features for hydroelectric plants. Also provided in Chapter 5 is general broad-based information or "rules of thumb" to allow the reader to assess if or when a structure has reached the end of its service life, or if the structure warrants or is capable of improvements to its performance.

Introduction to each feature

The format used in Chapter 5 starts with descriptions of the function of specific types of civil features, their problems and limitations, and possible corrective measures and alternative solutions for life extension or upgrade. Depending on the feature being described, not all aspects will contain the full range of information.

**Function:**

A brief description of the function or purpose of the feature is provided. Some civil features may have multiple uses as part of the hydroelectric project. Depending on the actual use and functions of the structure, its expected service life and opportunities for improvement can be determined.

**Problems:**

Typical problems and limitations (multiple if applicable) for the feature and the (root) causes are identified. If the civil feature has an operating system, a description of the limitations of the system is provided. Some problems are presented as a simple list and others are described in detail. General, broad-based "rules of thumb" regarding the service life, design or operational performance of a civil feature are provided as applicable. These are intended to provide

guidance as to whether a feature has reached the end of its life, or the feature and its function could be improved.

**Corrective Measures:**

Options are identified that have been used (or considered for use) to rectify the problems identified. For solutions with multiple alternatives, the pros and cons of the alternatives are discussed. However, the solution identified may be site specific, and may not be applicable to all similar problems.

**Opportunities:**

Possible opportunities (additional benefits) are identified for upgrading (improving) the civil feature beyond that associated with just addressing a problem or limitation of service life.

Table 5-3 is a summary of issues associated with the function of each type of structure which is described in Chapter 5 of the ASCE Guides, together with the corrective measures, techniques and applications that have been covered in the text.

Case Studies

By way of case studies, detailed example(s) are provided to describe typical solutions that have been used to address "real life" problems associated with that type of feature. In some of the examples the solutions may have extended the service life of a civil feature, improved its performance, or resulted in both an extension of service life and improvement of performance.

Each case study is structured to provide the following information:

- Background to the project and the function of the civil feature (background)
- Problems and causes (problem)
- Corrective measures and selected alternative (solution)
- Opportunities and benefits (results) provided to the owner as a result of life extension or upgrade

Table 5-3 is also an index to the case histories given in the ASCE Guides for each feature. This index identifies the project from which the case history is taken, the problem, solution and reference for further information.

References

There are three methods used in each Chapter to support the body of knowledge presented by the use of external resources.

- Best Collective Knowledge
- Technical References/Bibliography

- General Resources

The Best Collective Knowledge is a collection of references that supports the general descriptions of each civil feature, its function, challenges, solution and results. The references are located at the end of each section to which they are pertinent.

Technical References/Bibliography are references specifically identified in the text of these guides, designated by name and date (i.e. ASCE 1995) with the full reference at the end of each chapter.

General Resources include any background resource that is deemed to have value for broader reference and additional reading. It includes learned societies and government agencies as well as manufacturing and commercial organizations. The General Resources list may be found in Appendix A of the ASCE document.

**Table 5-3**
**Summary of Issues, Techniques and Applications**

| Section | Title | Issue Covered* | Applications / Opportunities | Case History |
|---|---|---|---|---|
| 5.1 | Intake Canals, Flumes and Forebays | • Deterioration of structures<br>• Reductions in cross sectional area<br>• Spalling of concrete lining<br>• Sedimentation<br>• Water loss through seepage<br>• Ice collection and pressure<br>• Debris collection | • Slope stabilization<br>• Coatings on slopes<br>• Removal of sediments<br>• Collection device for sediments<br>• Sealing joints with epoxy or membrane<br>• Ice booms or ice structure<br>• Debris booms or structures<br>• Dedicated breach section<br>• Repair and replace<br>• Upgrade operational design | 1. Emergency Breach of Canal Embankment (Flood Condition)<br>2. Ice Induced Failure of Forebay Skimmer Wall<br>3. Deterioration of Water Conveyance System |
| 5.2 | Tunnels, Shafts and other Undeground Openings | • Hydraulic losses<br>• Instability of rock<br>• Leakage - behind liners, through unlined rock<br>• Surging and transients<br>• Rockfalls<br>• Inadequate investigations of geotechnical conditions<br>• Fault zones<br>• Deterioration of linings | • Lining to reduce leakage or reduce friction<br>• Rock bolts etc. for stability<br>• Concrete or steel lining for stability<br>• Flexible membrane installation<br>• Replacing a penstock with a tunnel<br>• Effectiveness of surge chamber<br>• Grout voids<br>• Shotcrete lining | 1. Structural Instability of Tunnel<br>2. Leakage of Concrete Tunnel Liner<br>3. Inadequate Investigation of Subsurface Conditions<br>4. Fault Zones and Deteriorated Concrete Liner<br>5. Deteriorated Wood Pipeline (Replacement)<br>6. Tunnel Surge |
| 5.3 | Penstocks | • Support structural stability<br>• Leakage<br>• Hydraulic performance deterioration<br>• End of service life, failure<br>• Wall thining<br>• Foundation deterioration - settlement, faults, slides<br>• Ovaling, out of round<br>• Localized corrosion<br>• Aquatic growth (zebra mussels) | • Apply coatings to exterior to protect<br>• Apply linings to interior to decrease headloss, inhibit corrosion<br>• Repair joints, supports, anchors<br>• High pressure cleaning, relining<br>• Reduce friction losses<br>• Replace joints, supports and anchors<br>• Replace penstock with steel, wood, HDPE pipe | 1. Wood Stave Penstock Deterioration (Replacement)<br>2. Wood Stave Penstock Deterioration (Replacement)<br>3. Steel Penstock Deterioration and Failure<br>4. Foundation Movement<br>5. Deterioration and Increased Headloss |
| 5.4 | Tailraces | • Erosion<br>• Deposition - sedimentation<br>• Deterioration of walls and embankments<br>• High and low hydraulic conditions | • Excavation to lower tailwater level and increase head<br>• Protection measures to prevent erosion<br>• Structural raising tailwater level<br>• Repair of training walls<br>• Tailwater suppression system | 1. Low Seasonal Tailwater Level<br>2. Flood Erosion of Tailrace Embankment<br>3. Deteriorated Training Wall<br>4. High Tailwater Level |

* *Three key issues are common to all structures, namely; inadequate original design, change in performance criteria and deterioration of project components.*

## 5.6 Water Control Devices

Chapter 6 of the ASCE Guidelines introduces the perspective of how real problems associated with water control devices are identified, defined and implemented to extend the life or upgrade a hydroelectric project or dam.

The definition of life extension and upgrade as used in these guidelines is as follows:

Service Life Extension - Activity that extends the life of the civil feature beyond that which would be expected with normal maintenance (make it last longer).

Upgrade - Activity that improves performance of the civil feature beyond the current performance (make it work better). Exchange of a system or component with a similar or different system may not necessarily be considered an upgrade.

Chapter 6 Water Control Devices, Techniques and Applications is organised by principal project feature, namely gates and gate hoists, valves and operators and flashboards. This chapter describes examples and solutions as a way to illustrate techniques for improving the performance or extending the service life of civil features for hydroelectric plants. Also provided in Chapter 6 is general broad-based information or "rules of thumb" to allow the reader to assess if or when a structure has reached the end of its service life, or if the structure warrants or is capable of improvements to its performance.

Introduction to Each Feature

The format used in Chapter 6 starts with descriptions of the function of specific types of civil features, their problems and limitations, and possible corrective measures and alternative solutions for life extension or upgrade. Depending on the feature being described, not all aspects will contain the full range of information.

**Function:**

A brief description of the function or purpose of the feature is provided. Some civil features may have multiple uses as part of the hydroelectric project. Depending on the actual use and functions of the structure, its expected service life and opportunities for improvement can be determined.

**Problems:**

Typical problems and limitations (multiple if applicable) for the feature and the (root) causes are identified. If the civil feature has an operating system, a description of the limitations of the system is provided. Some problems are presented as a simple list and others are described in detail. General, broad-based "rules of thumb" regarding the service life, design or operational performance of a civil feature are provided as applicable. These are intended to provide guidance as to whether a feature has reached the end of its life, or the feature and its function could be improved.

**Corrective Measures:**

Options are identified that have been used (or considered for use) to rectify the problems identified. For solutions with multiple alternatives, the pros and cons of the alternatives are discussed. However, the solution identified may be site specific, and may not be applicable to all similar problems.

**Opportunities:**

Possible opportunities (additional benefits) are identified for upgrading (improving) the civil feature beyond that associated with just addressing a problem or limitation of service life.

Table 5-4 is a summary of issues associated with the function of each type of structure which is described in Chapter 6 of the ASCE Guides, together with the corrective measures, techniques and applications that have been covered in the text.

Case Studies:

By way of case studies, detailed example(s) are provided to describe typical solutions that have been used to address "real life" problems associated with that type of feature. In some of the examples the solutions may have extended the service life of a civil feature, improved its performance, or resulted in both an extension of service life and improvement of performance.

Each case study is structured to provide the following information:

- Background to the project and the function of the civil feature (background)
- Problems and causes (problem)
- Corrective measures and selected alternative (solution)
- Opportunities and benefits (results) provided to the owner as a result of life extension or upgrade

Table 5-4 is also an index to the case histories given in the ASCE Guides for each feature. This index identifies the project from which the case history is taken, the problem, solution and reference for further information.

References

These are three s methods used in each Chapter to support the body of knowledge presented by the use of external resources.

- Best Collective Knowledge
- Technical References/Bibliography
- General Resources

The Best Collective Knowledge is a collection of references that supports the general descriptions of each civil feature, its function, challenges, solution and results. The references are located at the end of each section to which they are pertinent.

Technical References/Bibliography are references specifically identified in the text of these guides, designated by name and date (i.e. ASCE 1995) with the full reference at the end of each chapter.

General Resources include any background resource that is deemed to have value for broader reference and additional reading. It includes learned societies and government agencies as well as manufacturing and commercial organizations. The General Resources list may be found in Appendix A of the ASCE document.

**Table 5-4**
**Summary of Issues, Techniques and Applications**

| Section | Title | Issue Covered* | Applications / Opportunities | Case History |
|---|---|---|---|---|
| 6.1 | Gates and Gate Hoists** | • Functional obsolescence/non-performance<br>• Gate failure<br>• Excessive corrosion<br>• Inadequate maintenance: personnel safety, excessive cost<br>• Loss of power<br>• Hoist motor overload and level switch failure<br>• Gate vibration<br>• Improper lake level systems<br>• Restricted gate movement<br>• Alkali-aggregate reactivity damage<br>• Seal rolling<br>• Bearing failure, greased and self lubrication<br>• Debris and/or ice jamming<br>• Discharging debris and ice | • Ice removal systems: heat trace, air bubblers<br>• Rubber dam replacing gates or flashboards<br>• Replace or upgrade gate or hoist<br>• Replace gate seals and sealing plates<br>• Maintenance bulkheads<br>• Corrosion resistant bearings<br>• Coatings to prevent corrosion | 1. Poor Sealing and Gate Closure<br>2. Tainter Gate Leakage, Freezing and Concrete Deterioration<br>3. Trunnion Pin Failure<br>4. No Provisions for Maintenance Bulkheads<br>5. Excessive Movement and Tainter Gate Failure<br>6. Insufficient Gate Capacity and Loss of Generation<br>7. Uncontrolled Flashboard Failures<br>8. Safety Concerns with Antiquated Gate Operator |
| 6.3.1 | Valves and Operators*** | • Infrequency of use and overuse<br>• Severity of operating environment<br>• Variations in operating range and application<br>• Maintenance difficulties<br>• Remote operation and control issues<br>• Catastrophic failure<br>• Valve leakage<br>• Seals and bearing problems<br>• Corrosion/erosion<br>• Self-closing tendencies<br>• Deterioration and end of service life | • Improved control of movement and range<br>• Decreased maintenance<br>• Increased reliability<br>• Replacement with different type of valve<br>• Improvements in hydraulic performance<br>• Application of abrasion and corrosion resistant valves | 1. Safety and Operational Concerns |

| Section | Title | Issue Covered* | Applications / Opportunities | Case History |
|---|---|---|---|---|
| 6.4.1 | Flashboards**** | • Inopportune removal or failure resulting in loss generation<br>• Failure and damage from debris or ice<br>• Inability and increased costs to replace failed flashboards<br>• Over-designed<br>• Inadequate recreation and navigation depths<br>• Increased leakage and spillage<br>• Personnel safety during maintenance/installation | • Increased revenues by decreasing spillage and maintaining head<br>• Improve personnel safety and reduced maintenance<br>• Enhanced environmental and recreational and operating conditions | 1. Flashboard Operation Misunderstanding<br>2. Flashboard Failure Due to Ice and High Flows<br>3. Personnel Safety, Lost Generation and O&M Costs<br>4. Insufficient Spillway Capacity and Loss of Flashboards<br>5. Over-Design of Flashboards and Failure of Spillway Crest |

* *Three key issues are common to all structures, namely; inadequate original design, change in performance criteria and deterioration of project components.*

** *Additional information on gates and gate hoists can be found in Appendix C, Table C-1.*

*** *Additional information on valves or operators can be found in Appendix C, Tables C-2 and C-3.*

**** *Additional information on flashboards can be found in Appendix C, Table C-4.*

## 5.7 Other Practical Considerations

Chapter 7 of the ASCE Guidelines introduces the perspective of how other practical considerations (project features and systems) associated with civil features are identified, defined and implemented to extend the life or upgrade a hydroelectric project or dam. These features and systems, integral to the operation of the hydroelectric facility include:

- Civil Works Systems
  - (a) structural instrumentation,
  - (b) pressure relief systems,
  - (c) flood proofing, and
  - (d) oil containment systems
- Systems Critical for Emergency Operations - ancillary systems such as
  - (a) electric backup power,
  - (b) communications, and
  - (c) access during emergencies
- Recreational Project Safety
- Project Security

The purpose of Chapter 7 is to re-acquaint owners and other decision makers with and introduce engineers specializing in other disciplines to the salient characteristics of these features. Failure of any of these systems can occur under non-emergency (e.g. routine operation or periodic testing) or emergency conditions. Because of the unique nature of each facility and the sensitivity of these systems to nuances of design and construction, any project involving life extension and or upgrading ***must***, by definition take into account these supporting systems.

The focus of the subsections in Chapter 7 differs from the discussion in the previous chapters of the ASCE Guidelines, in that they are overviews as to the criticality of some subsystems which often form part of a life extension or rehabilitation project.

## 5.8 Appendices to ASCE Guide

There are three Appendices to the ASCE Guide.

*Appendix A: Hydroelectric and Dam Engineering, Library of General Resources.*

This appendix includes references to documents from ten major sources, including institutions, agencies, organizations and private companies. Included are:

- General Hydroelectric Design and Operation
- American Society of Civil Engineers

- Association of the Dam Safety Officials
- Electric Power Research Institute
- Federal Energy Regulatory Commission
- Industry Publications
- US Army Corps of Engineers
- US Bureau of Reclamation
- United States Society on Dams
- Other Resources

*Appendix B: Project Information*

This appendix describes the various types and sources of information to be used during planning evaluation and implementation phases for life extension and upgrade projects for dams and hydroelectric facilities.

*Appendix C: Tables*

This appendix includes tables containing information on various civil features and issues associated with them. Included are:

- Gate Types and Use of Gates
- Valve Types and Applications
- Causes of Common Valve Problems
- Flashboards
- Floodproofing Measures at Powerhouse
- Powerhouse and Dam Flood Proofing Consideration

# 6
# CHAPTER 6: REFERENCES


EPRI 1999 *Hydro Life Extension Modernization Guides, Volume 1: Overall Process, EPRI, Palo Alto, CA: 1999. TR-112350-V1*

EPRI 2000 *Hydro Life Extension Modernization Guide, Volume 2. Hydromechanical Equipment, EPRI, Palo Alto, CA: 2000. TR-112350-V2.*

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EPRI 2001 *Hydro Life Extension Modernization Guide, Volumes 4 and 5: Auxiliary Mechanical and Electrical Systems, EPRI, Palo Alto, CA: 2001. TR-112350-V4.*

EPRI 2000 *Hydro Life Extension Modernization Guide, Volume 7: Protection and Control, EPRI, Palo Alto, CA: 2000. TR-112350-V7.*

ASCE 2005 *Guidelines for Life Extension and Upgrade of Civil Works for Hydroeoectric Facilities, ASCE, New York, New York, 2005.*

ASCE 1992 *Guidelines for Life Extension and Upgrade of Civil Works for Hydroeoectric Facilities, ASCE, New York, New York, 1992.*

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# CASE HISTORY

## A1 Synopsis

The purpose of the Case History is to demonstrate the civil aspects of Life Extension and Modernization methodology as presented in these guidelines. The Case History is intended to be realistic but, in order to conduct the demonstration in a clear and concise manner, certain simplifications have been made. The scenarios under investigation normally would be far more complex than those documented here and many more life extension and modernization timing issues would be investigated. Also, licensing and regularly matters would require consideration in terms of the timing and nature of any amendments to be sought.

The level of detail presented illustrates that expected to be uncovered when the process is conducted on a 'live' plant. Financial details are based on generic North American data but, in some areas, have been altered to assist the process. Each utility will have their own criteria for determining a 'viable' project and it is not the intention of this Case History to argue the viability or otherwise of the scenario in question but merely to demonstrate the steps in the process.

The Case History conducts the screening and priorization process for these civil components and shows that the Hydro development is a high ranking candidate for life Extension and Modernization. The Life Extension and Modernization Plan shows that the plant has significant requirements for life extension with modernization opportunities available for increased energy output.

The feasibility process refines the information used in the Life Extension and Modernization Plan to show the viability of the proposed modernization activities.

The project definition and implementation section is a summary of the process to obtain project approvals and put in place the steps for delivery of the project.

## A2 Background

The Hydro development used as the basis of this Case History is an amalgam of civil structures, equipment and features selected to illustrate the process. The civil components of this development consist of:

- A spillway with ageing flashboards and visual evidence of AAR activity

- Water conveyance features including canals, conduits and penstocks
- Power intakes protected by debris boom
- A composite concrete faced rockfill dam with significant leakage
- A historic powerplant

The civil components of this development were built 50 years ago. The reservoir is of medium size and surrounded by steep slopes and mature forests with localized logging activity. The reservoir fluctuates 10 ft (3 m) but is normally at full pool. Approximately 11% of inflows are passed over the spillway.

## A3 Screening and Prioritization

Using the criteria developed in Volume 1, Section 3, the Hydro development is a candidate for the screening and prioritization process as it is:

- more than 15 years old
- has not had a life cycle evaluation completed within the last 5 years
- has suffered a decline in condition and performance based on visual inspections

### *A3.1 Life Extension Indicators*

The life extension ratings are based on the Indicators and assessment parameters including in Section 3.2 of Volume 6. These are summarized in Table A3-1.

Condition:

- there is evidence of structural deterioration of the powerplant
- there is a lack of knowledge on the condition of the canal.

Condition is a potential driver for Life Extension.

Performance:

there is evidence of AAR activity at the spillway

there are significant seepage losses through the dam

Performance is a potential driver for Life Extension.

Operational Risk:

- there is a potential for failure of a small portion of the canal

Operational Risk is a potential driver for Life Extension

Cost:

- the maintenance cost for the civil works are higher than industry average (based on Section 3.3 of Volume 6).

Cost is a potential driver for Life Extension.

Environmental Issues:

- Management of reservoir debris

Environmental Issues are a potential driver for Life Extension.

Catastrophic Risk:

- none

Catastrophic Risk is not a potential driver for Life Extension.

### *A3.2 Modernization Indicators*

The modernization ratings are based on the Indicators and assessment parameters included in Section 3.4 of Volume 6. These are summarized in Table A3-1.

Capacity:

- None

Capacity is not a potential driver for Modernization

Efficiency:

- Improvements can be made to seasonal non-flood storage
- Losses in the water conveyance system can be reduced.

Efficiency is a potential driver for Modernization.

Equipment:

- Debris frequently blocks the power intakes
- Improved debris management equipment is available

Equipment is a potential driver for Modernization.

Range of Products:

Reservoir could support recreational use

No mechanism available to develop recreation

Range of Products is not a potential driver for Modernization.

### *A3.3 Summary of Indicators*

For the civil assets rated in the Case History for the Hydro development, indicators are positive for both life extension and modernization. The next step will therefore be the development of a life extension and modernization plan. As part of the work activities to develop this plan, the screening process for life extension indicates that issues around concrete structural deterioration, AAR, seepage losses through the dam, high maintenance costs and reservoir debris need to be carefully assessed. As part of the assessment of modernization activities, improving reservoir storage volumes and reducing losses in the water conveyance system are potential opportunities.

The results are summarized in Table A3-1.

**Table A3-1**
**Civil and Other Plant Components**
**Summary of Screening Indicators**

Project: _____
Civil Component Name: _____
Asset No.: _____
Prepared by: _____
Date: _____

| Is Life Extension Indicated by: | | | Is Modernization Indicated by: | | |
|---|---|---|---|---|---|
| Dependability | Yes | No | Output | Yes | No |
| - Condition | ☑ | ❒ | - Capacity | ❒ | ☑ |
| - Performance | ☑ | ❒ | - Efficiency | ☑ | ❒ |
| - Operational Risk | ☑ | ❒ | - Equipment | ☑ | ❒ |
| - Cost* | ☑ | ❒ | | | |
| Comments: | | | Comments: | | |
| Sustainability | Yes | No | Flexibility | Yes | No |
| - Environmental Issues | ☑ | ❒ | - Range of Products | ❒ | ☑ |
| - Catastrophic Risk | ❒ | ☑ | | | |
| Comments: | | | Comments: | | |

* including assessment of cost allocation criteria

## A4 Life Extension and Modernization Plan

Preparation of a Life Extension and Modernization (LEM) Plan is the fundamental process to "Identify" those activities required to extend the life of the project in the most cost effective manner, and those activities which could enhance the value of the facility. In both cases it is inherent in the process that the level of service derived from the Hydro development be maintained or improved.

The process to develop the LEM plan is documented in Section 4 of Volume 1 as well as Section 4 of the other technical volumes. This is shown diagrammatically in Figure A4-1.

In this Case History for selected civil assets of the Hydro development only key highlights will be documented. Therefore the process has been subdivided into five main activities.

- Undertake Plant Survey for civil assets
- Develop Strategies
- Select Needs and Opportunities
- Evaluate Benefits and Costs (Financial Evaluation)
- Prepare Life Extension and Modernization Plan

### *A4.1 Plant Survey (for Civil Assets)*

The plant survey for the civil assets involved:

- Planning the process
- The formulation of an asset register (asset hierachy)
- The collection of existing data including:
  - reports of previous assessments, studies, tests and projects
  - operational and performance information
  - maintenance and cost records
  - design records
- Analyzing the collected data prior to the site visit.
- Conducting a site visit monthly using 2 civil engineers. The visit took one day and involved inspection of all the civil assets and interviews with site staff to ascertain condition and performance. No units were taken out of service for inspection and no specific testing occurred during this visit. Additional records were reviewed at the site.
- Collating the data (Table A4-1).

- Conducting a risk assessment for the civil structures with the assessment collated in Table A4-2.
- Formulating a 'Needs table' (Table A4-3 Needs) along with an 'Opportunities' table (Table A4-4 Opportunities).

The four tables (A4-1 to A4-4) used to demonstrate the Plant Survey only cover selected aspects of the civil assets. Documentation of the entire civil and other plant components of a project such as the Hydro development would cover many sheets in tabular form.

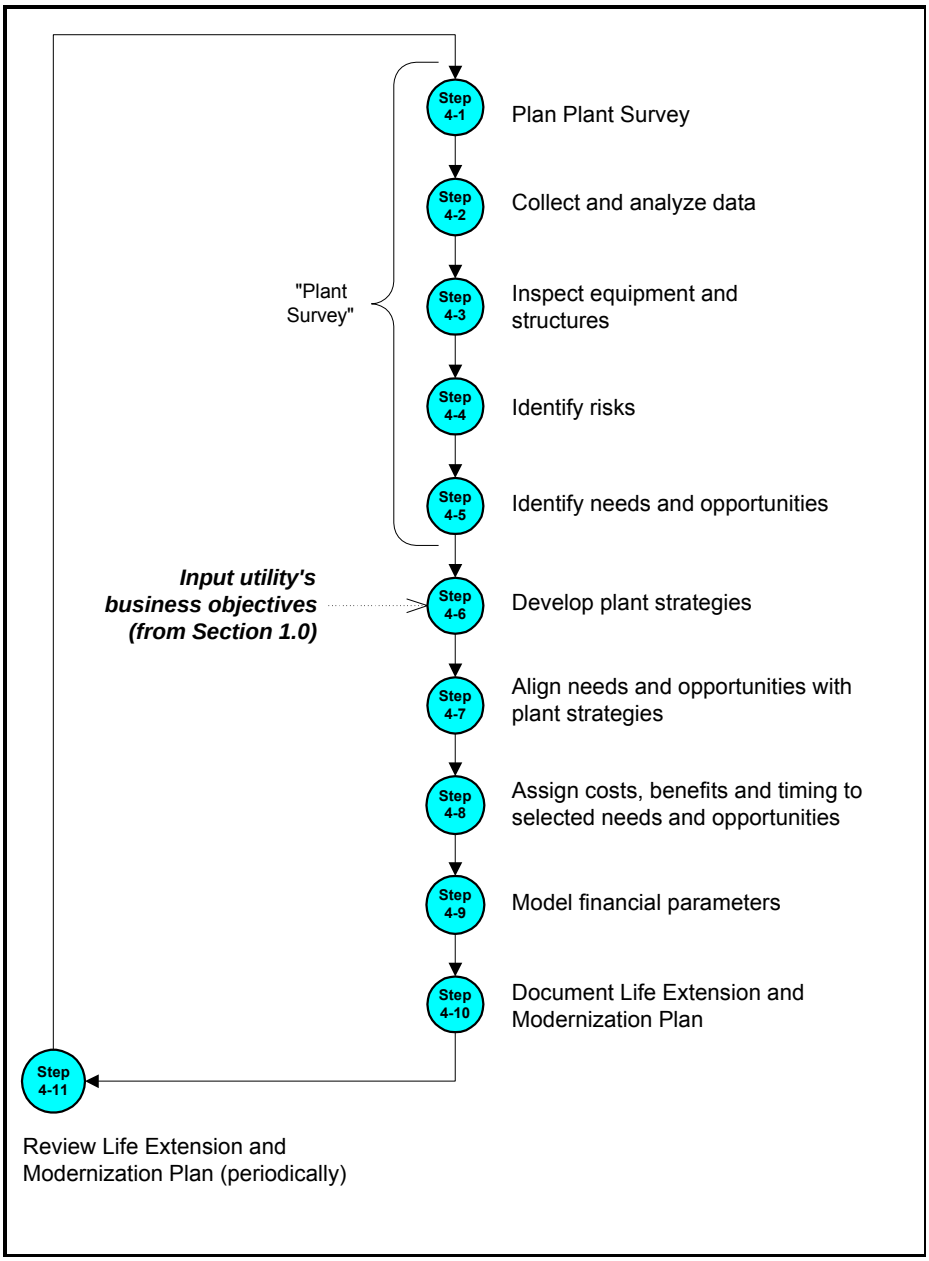


**Figure A4-1**
**Life Extension and Modernization Plan**

**Table A4-1**
**Data Analysis and Inspection Results Table for Equipment and Structures**

| Asset No. | Structure | Performance Information | Results of Assessment | Possible Life Extension Needs | Activities/Projects to meet Needs (including timing and cost) | Possible Modernization Opportunities | Activities to achieve opportunities (including timing and cost) |
|---|---|---|---|---|---|---|---|
| **2.0** | **Powerplant** | | | | | | |
| **2.4** | **Civil Works** | | | | | | |
| | **Powerhouse Structure** Consists of mass reinforced concrete from the foundation to the generator floor level. From the generator floor to the roof, the superstructure consists of structural steel frames partially encased in reinforced concrete. | • The powerhouse foundation uplift pressures are controlled by relieving high artesian aquifer pressures with ”bleeder wells”. | • Installation of “bleeder wells” has stabilized the powerhouse.<br>• During the rainy season, water leaks into the cable adit through construction and contraction joints.<br>• Conduct seismic evaluation Phase II. | • Maintain “bleeder wells”.<br>• Add drains to prevent water leakage into the cable adit.<br>• Carry out any recommendations of the seismic evaluation. | • Add drains to prevent water leakage into the cable adit in 2005 - $25k.<br>• Seismic evaluation Phase II and Phase I early attention items in 2004 - $200k. | • Nil | • Nil |
| | | • Machine Hall and Control Building are original construction. Powerhouse is located in a National Park and is designated a "Historic Building". | • Machine Hall and Control Building exterior shows surface pattern cracking and structural cracking located at corners of openings. Lunch room outer edge has settled resulting in ¾ inch gap at top of connection with Machine hall. Interior areas clean and well organized.<br>• Minor leaks noted inside powerhouse. Cracks and holes in roof membrane observed. Some areas have alligator crack pattern on surface. | • Exterior concrete buildings; fill cracks, repair spalls and recoat with coloured concrete sealer. Lunch room; check foundation bearing and wedge up outer edge. Also seal joint at wall connection. Control Building interior; update - replace flooring and redecorate. | • Remove loose material; patch and seal $25k in 2004, $25k in 2018<br>• Patch roof membrane, $25k in 2004<br>• Replace roof membrane $270k in 2008<br>• Lunch room, seal open crack $5k in 2004<br>• Update interior flooring $25k in 2004 | • Exterior; install covering to match more recent buildings constructed in National Park. Fire protection; review and update.<br>• Upgrade powerhouse to National Park architecture standards. | • Seal exterior to improve appearance $145K in 2006.<br>• Landscape grounds to shield equipment $10K in 2005.<br>• Architectural improvements $80K in 2005. |
| **4.0** | **Dam, Forebay and Reservoir** | | | | | | |
| **4.1** | **Dam** | | | | | | |
| 4.1.1 | **Dam Structure** The dam is a 90 ft high by 650 ft long zoned rockfill embankment with shotcrete facing | • Shotcrete facing was placed 30 years ago. Recently seepage though structure has increased significantly. | • Underwater surveillance using ROV's has failed to identify underwater cracks.<br>• Full drawdown not | • Requires full impervious membrane on upstream face to cut off seepage flows. | • Geomembrane installed underwater on upstream face, with buttress support $3 million in 2005. | • Nil | • Nil |

| Asset No. | Structure | Performance Information | Results of Assessment | Possible Life Extension Needs | Activities/Projects to meet Needs (including timing and cost) | Possible Modernization Opportunities | Activities to achieve opportunities (including timing and cost) |
|---|---|---|---|---|---|---|---|
| | | Localized patching has slowed seepage temporarily. | possible due to environmental impacts. | | | | |
| 4.1.4 | **Debris Booms**<br>Two debris booms are located upstream of approach channel and a single boom is located immediately upstream of the dam.<br>• Primary upstream boom, 2000 ft long extends across forebay and consists of single logs connected with boom chains.<br>• Secondary upstream boom, 1200 ft long extends from near abutment to water gauge and consists of singe logs connected with boom chains.<br>• Dam boom, 300 ft long extends across approach channel and consists of single logs connected with boom chains. | • Primary upstream boom used to collect debris from freshet or storms and transport to salvage and disposal area. All three booms failed in 1995 during exceptional storm event that caused reservoir slides, design jams in tributaries and resulted in 250 acres of reservoir debris at the dam site. | • Debris booms inspected and repaired every five years. Debris booms replaced every fifteen years. | • Replace secondary boom with full cable and triple log arrangement attached to cable. | • New secondary boom: $100K in 2005, $100K in 2020<br>• Primary and Dam booms: $50k in 2008. | • Nil | • Nil |
| 4.2.3 | **Dam Forebay and Reservoir**<br>The forebay extends approximately 1500 ft from the dam to the highway bridge upstream and varies in width from 300 ft to 600 ft. Inflow entering the forebay carries a considerable amount of sediment during the spring freshet. Some of the sediment is passed over the spillway with the remainder passing through the units or being deposited throughout the headpond. | • Before 1970, sediment trapped was flushed through outlets in dam.<br>• 1971 to 1985, dredge discharged sediment over spillway (annual activity)<br>• 1985 to present, dredge discharged sediment in disposed area. | • Load following is not a requirement for the plant, therefore loss of storage does not directly affect powerplant operations.<br>• Cooling water system silt clogging problems to be overcome with new filter system on order.<br>• Erosion damage to turbine runners increases with quantity of silt passed through units. However, weld repair at 5-10 year intervals is much cheaper than annual | • Monitor sediment build-up annual. | • Nil - Dredging costs are maintenance items. | • Operational changes to minimize dredging requirements. | • Nil - Operational changes are revenue neutral. |

| Asset No. | Structure | Performance Information | Results of Assessment | Possible Life Extension Needs | Activities/Projects to meet Needs (including timing and cost) | Possible Modernization Opportunities | Activities to achieve opportunities (including timing and cost) |
|---|---|---|---|---|---|---|---|
| | | | dredging. | | | | |
| **5.0** | **Spillway, Intakes and Outlet Works** | | | | | | |
| **5.1.1** | **Spllway Structure**<br>Spillway is a free overfall type, centrally located on the dam and terminating in a reinforced concrete stilling basin. A reinforced concrete bridge provides access over the dam. The spillway designed for PMF. The flashboards on the spillway crest increase active storage. To protect flashboards from ice loading during winter months, an air bubbler system was installed. Spillway has three central piers which divide spill opening into four 35 ft wide channels or net crest length of 140 ft. The spillway flow is contained by reinforced concrete retaining walls on each side of the chute which extends 160 ft downstream of the dam axis to the weir. | • The spillway operates about 17-20 days per year. Some defects in the hydraulic surfaces can be tolerated. Review of flashboard and operation required. | • Spalling of ogee surface, deepest at block joint. Aggregate exposed in areas of the stilling basin. Spalling of left wall top surface, repair not required for spillway operation. | • Inspect spillway following major spillways and repair areas showing rapid deterioration.<br>• Repair swirl holes in stilling basin if they develop. Repair major spalls on ogee to maintain hydraulic surface. | • Repair spalls $25k in 2005, $25k in 2015. | • Repair spall on top of left wall to match appearance of similar National park structures. | • Architectural improvements $30K in 2005. |
| **5.1.4** | **Spillway Flashboards**<br>Flashboard panels were installed in 1956 on the spillway crest, four to each channel. Each flashboard panel is supported by a groved shear bolt at each side. Groves in the bolt have been designed to fail at head of 8 ft for central units and 10 ft for others. | Flashboards inspected and rotten boards replaced about 6 years ago. The carpenter retired and has not been replaced. | • Flashboards were not inspected up close. Normal access is by boat and the reservoir level was too low at start of program. Later, spill started with combination of heavy rain and both units off line. As discussed in the Dam Safety Report, release of the flashboards is not guaranteed during a high water event. Release requires the support angle to slide off the post when the | • Continued inspection and replacement of weak/rotten boards as required. Inspection and maintenance of the support angles, paying close attention to the sliding surfaces. | • Investigate reliability of flashboards to fail as designed under flood $50k in 2004. | • A number of modernization options could be considered.<br>1. Remove flashboards and loose head and storage.<br>2. Modify flashboards to ensure their release.<br>3. Rubber dams.<br>4. Hydro-plus or similar auto release barriers | • Replace flashboards with fusegate $250K in 2006 |

| Asset No. | Structure | Performance Information | Results of Assessment | Possible Life Extension Needs | Activities/Projects to meet Needs (including timing and cost) | Possible Modernization Opportunities | Activities to achieve opportunities (including timing and cost) |
|---|---|---|---|---|---|---|---|
| | | | shear bolt fails. however,. rust on the contact surface may prevent release at levels required for. | | | | |
| **5.2.2** | **Intake Trashracks**<br>Two sets of inclined trashracks are installed in guides on the inlet to the power tunnel. Each set of trashracks is made up of two sections. The trashracks are of welded steel construction. Each trashrack section is 16 ft high by 11 ft wide. | • The trashracks were replaced in 1986. The racks are raised and inspected approximately once every five years.<br>• The trashracks were installed as part of the original plant. In the 1987 inspection of the waterways, it was reported that the trashracks were partially plugged with debris. In 1993 the racks were removed, cleaned and galvanzied. They were again partially plugged with debris. | • The trashracks are submerged and could not be inspected as part of the plant inspection. However based on the documentation n the previous inspections, the racks should be satisfactory for extended life. | • Nothing required. | • Nil | • A trashrack monitoring device to measure head loss due to debris and hence optimize debris removal. | • Trashrack headloss monitoring equipment $50k in 2006. |
| **6.0** | **Conduits** | | | | | | |
| 6.1 | **Penstocks**<br>Consist of 4 surface, steel penstocks. Lengths vary from 1700 to 2000 ft. All penstocks have an I.D. of 8 ft-6 inch, the elevation difference from the start of the penstocks (at the PIV) to the end of the penstocks (at the TIV) is ~426 ft. | | • Good condition, minimum life expectancy - 20+ years with regular maintenance.<br>• There is a concern regarding the stability of the surface penstock hillside which requires attention. | • Routine maintenance.<br>• Check condition of protective coatings and renew protective coatings when required.<br>• Carry out seismic evaluation.<br>• Study stability of penstock footings.<br>• Remove rocks and debris from beneath penstocks.<br>• Install rock barriers in penstock trench. | • Inspect all penstocks and evaluate condition of interior protective coatings /surface in 2004- $200k.<br>• Study surface penstock footings in 2004 - $20k.<br>• Study surface penstock hillside in 2004 - $40k.<br>• Remove rocks and debris in 2005 - $20k.<br>• Conduct seismic evaluation in 2006 - $40k. | • Nil | • Nil |

| Asset No. | Structure | Performance Information | Results of Assessment | Possible Life Extension Needs | Activities/Projects to meet Needs (including timing and cost) | Possible Modernization Opportunities | Activities to achieve opportunities (including timing and cost) |
|---|---|---|---|---|---|---|---|
| 6.6.1 | **Canal Structure**<br>The canal, with siphon, concrete pipe and tunnel diverts water from an adjacent catchment to the reservoir. | The canal is generally in good condition except in one area where there is extensive leakage and sloughing of surrounding slopes. Visual impact high. | • Leakage is from cracks and joints probably caused by a aggravating local sloughing of slopes. | • New lining required for 2500 ft of canal and rehabilitation of unstable slopes as well as revegetation. | • Investigation, preparation and installation of impervious membrane $150k in 2006.<br>• Rehabilitation of slopes and revegetation $100k in 2006. | • Nil | • Nil |

**Table A4-2**
**Risk Identification**

| Columns | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Heading | Component | | Failure Mode | | Likelihood | Consequences | | | Risk | | Risk Management | | Risk Mitigation | | | | | Overall importance of risk issues |
| Description Project | Asset No. | Equipment, Structure, Other | What hazards could occur? | What could happen? | How likely is it to happen? | Financial | Life Safety | Environmental Social | Risk Category | Risk Rating | Are there processes in place to manage risk/what are they? | Are they effective? | Is risk mitigation necessary? | Will the activity be an investigation? Y/N | Will the activity be a project? Y/N | What is the approximate per unit cost? ($K) | What is the likely timing? | |
| | **2.0 POWERHOUSE** | | | | | | | | | | | | | | | | | |
| | 2.4.1 | Powerhouse Structure | E&P Foundation movement failure of structure "bleeder wells" plug of cable adit water damage | Loss in capacity/ loss of generation/ | | | | | F | | Y; OMS | Y | Y | N | Y | $25 | 2005 | |
| | 2.4.1 | Powerhouse Structure | N(e) Structural failure | Damage to powerplant struct. resulting in loss of capacity/generation /service. Loss of life (office). | | | | | LS; F | | N | - | Y | N | Y | $200 | 2004 | |
| | 2.4.1 | Powerhouse Structure | E&P - Deterioration due to age | Damage to powerplant resulting in loss of capacity /generation/ service. | | | | | F | | Y;OMS | Y | Y | N | Y | $350 | 2004 to 2008 | |
| | **4.0 DAM, FOREBAY AND RESERVOIR** | | | | | | | | | | | | | | | | | |
| | 4.1.1 | Dam Structure | E&P - Differential settlement crack causes excessive seepage. | Loss of reservoir resulting in loss of capacity/ generation/energy/ loss of rights/ environmental damage /lose access. | | | | | BC | | Y; Inspection/ OMS/EERP/LOO | Y | Y | N | Y | $3,000 | 2005 | |
| | 4.1.4 | Debris Booms | N(f) Debris boom fails and debris blocks power intake or plugs spillway. | Loss of generation and reduction in spillway capacity during flood. | | | | | F | | Y; OMS, LOO | Y | Y | N | Y | $150k | 2005 to 2008 | |
| | 4.2.3 | Dam Forebay and Reservoir | N (f) E& P Comp. Headpond fills with sediment damaging units. | Loss of generation, environmental damage and loss of rights. | | | | | F | | Y; Inspection, OMS, EERP, LOO | Y | Y | Y | N | None | N/A | |
| | **5.0 SPILLWAY, INTAKES AND OUTLET WORKS** | | | | | | | | | | | | | | | | | |
| | 5.1.1 | Spillway Structure | E&P - Deterioration due to age | Damage to spillway resulting in reduction in usage | | | | | F | | Y; Inspection, OMS, LOO | Y | Y | N | Y | $25k | 2005 | |
| | 5.1.4 | Spillway Flashboards | N (f). Comp. Flashboards fail to collapse as intended resulting in higher reservoir levels. | Overtopping of dam causing damage and loss of rights. | | | | | F | | Y; Inspection, OMS, EERP, LOO | Y | Y | Y | Y | $300k | 2004 to 2006 | |
| | 5.2.2 | Intake Trashracks | E&P - Trashracks are plugged with debris | Loss or reduction in generation | | | | | F | | Y; Inspection/OMS | Y | Y | Y | Y | $50 | 2006 | |
| | **6.0 CONDUITS** | | | | | | | | | | | | | | | | | |
| | 6.1.1 | Pipe | E&P deterioration due to age. | Loss of generation | | | | | F | | Y; OMS | Y | Y | Y | Y | $120 | 2004 to 2006 | |
| | 6.6 | Canal and Headworks | E&P - Failure of concrete lined canal | Loss of generation | | | | | F | | Y; Inspection/testing /OMS/LOO | Y | Y | Y | Y | $250 | 2006 | |

**Risk Assessment Spreadsheet**
**Reference Tables for Use with Spreadsheet**

**Table (A) - Hazard Codes**

| Hazard Code | Description |
|---|---|
| N(e) | Natural (extreme) Earthquake |
| N(f) | Natural (extreme) Flood |
| N(s) | Natural (extreme) Storm |
| S(f) | Security Fire |
| S(sv) | Security Sabotage/Vandalism |
| Comp | Compliance - Loss of Water Use |
| E&P | Environment and Production |

**Table (B) - Category Codes**

| Risk Category Code (Column 9) | Description |
|---|---|
| F | Financial |
| LS | Life Safety |
| BC | Business Critical |

**Table (C) - Risk Management Processes**
(column 11)

| | |
|---|---|
| Contingency Plan | |
| EPP | Emergency Preparedness Plans |
| EERP | Environmental Emergency Response Plans |
| OMS | Operating Maintenance and Surveillance |
| ECS | Emergency communication system |
| | |
| Procedure Changes | |
| LOO | Local operating order/operations changes |

## Table A4-3
## Needs

| Asset No. | Equipment/ Structure | Source of Information | Cost Category | Product Description | Total Cost $k | Service Life | Starting Year | Cost per Activity per Year in PV $ | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
| 2.4.1 | Powerhouse Structure | | | Add drains to prevent water leakage into the cable adit | 25 | 25 | 2005 | 25 | | | | | | | | | | | | | | | | | | | | |
| 2.4.1 | Powerhouse Structure | | | Seismic evaluation | 200 | 0 | 2004 | 200 | | | | | | | | | | | | | | | | | | | | |
| 2.4.1 | Powerhouse Structure | | | Repairs to structure | 375 | 20 | 2004 | 80 | | | | 270 | | | | | | | | | | | 25 | | | | | |
| 4.1.1 | Dam | | | Geomembrane on front face | 3000 | 50 | 2005 | | 3000 | | | | | | | | | | | | | | | | | | | |
| 4.1.4 | Debris boom | | | Replace debris boom | 250 | 15 | 2005 | | 100 | | | 50 | | | | | | | | | | | | 100 | | | |
| 5.1.1 | Spillway structure | | | Repair structure | 50 | 10 | 2005 | | 25 | | | | | | | | | | 25 | | | | | | | | |
| 5.1.4 | Flashboards | | | Investigate reliability | 50 | 0 | 2004 | 50 | | | | | | | | | | | | | | | | | | | | |
| 6.1 | Penstocks | | | Inspect all penstocks and evaluate interior protective surface | 200 | 50 | 2004 | 200 | | | | | | | | | | | | | | | | | | | | |
| 6.1 | Penstocks | | | Study surface penstock footings | 20 | 0 | 2004 | 20 | | | | | | | | | | | | | | | | | | | | |
| 6.1 | Penstocks | | | Study surface penstock hillside | 40 | 0 | 2004 | 40 | | | | | | | | | | | | | | | | | | | | |
| 6.1 | Penstocks | | | Remove rocks and debris | 20 | 50 | 2005 | | 20 | | | | | | | | | | | | | | | | | | | |
| 6.1 | Penstocks | | | Conduct seismic evaluation | 40 | 0 | 2006 | | | 40 | | | | | | | | | | | | | | | | | | |
| 6.6 | Canals | | | Repair leaks and rehabilitate slope | 250 | 25 | 2006 | | | 250 | | | | | | | | | | | | | | | | | | |
| **Identified Project - Total** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Unspecified Projects - Allowance of 20% of Annual Average** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Total** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## Table A4-4
## Opportunities

| Asset No. | Equipment/ Structure | Source of Information | Cost Category | Product Description | Total Cost $k | Service Life | Starting Year | Cost per Activity per Year in PV $ | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
| 2.4.1 | Powerhouse | | | Upgrade to National park architecture standards | 235 | 35 | 2005 | | 90 | 145 | | | | | | | | | | | | | | | | | | |
| 5.1.1 | Spillway structure | | | Upgrade to National park architecture standards | 30 | 35 | 2005 | | 30 | | | | | | | | | | | | | | | | | | | |
| 5.1.4 | Flashboards | | | Replace flashboards with fusegates | 250 | 35 | 2006 | | | 250 | | | | | | | | | | | | | | | | | | |
| 5.2.2 | Trashracks | | | Design and implement. Trashrack monitoring equipment. | 50 | 35 | 2006 | | | 50 | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Identified Project - Total** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Unspecified Projects - Allowance of 20% of Annual Average** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Total** | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## *A4.2 Strategies*

Plant strategies were formulated to assist in determining the future direction of the Hydro plants. To capture the important decision-making areas of plant management, strategies were developed for:

- Operations
- Workforce and maintenance planning
- Risk
- Product portfolio improvements

**Operations:**

The plant operation is normally at full capacity during high load hours and synchronous condensing during low load hours. This mode of operation is restricted by environmental considerations and there is little scope for change from this operating regime. The opportunity remains, however, to gain some more energy from increasing storage water in the non flood season. Projects that can maintain higher reservoir levels and increase storage will be viewed favourably.

**Workforce and Maintenance Planning:**

The powerplant was automated in the early 1990's and has no operational staff. Plant maintenance staff are presently shared with other plants in the area and further optimization is not envisaged. The numerous costs for the civil components are higher than industry averages. However the condition of the dam and the extensive network of canals and other water conveyance structures is the reason. Projects that reduce maintenance requirements and which automate surveillance operation will be considered positively. Contracting out of non-core business will also be considered.

**Risk:**

Risks associated with the civil components of the hydro plant will be addressed in the following manner (see Table A4-2);

- Life Safety - All regulatory requirements shall be met. If the regulatory requirements are not being met in any area they will be addressed immediately. Dam safety risks, which relate to life safety risk to the public, are addressed by procedures internal to the utility.
- Business Critical Risks - Generally business critical risks relate to dam safety (for this plant) and will be addressed by internal procedures.
- Financial Risks - Financial risks will be assessed for impact on the plant's operation. The risk exposure will be identified and projects which reduce the plant's risk exposure will be justified using economic/financial criteria.

**Product Portfolio Improvements:**

Automation in the early 1990's allowed the plant to be operated under automatic generation control (AGC) and there is little scope for an improvement in the portfolio of products supplied at the powerplant. With regard to the civil components, any project that enhances environmental benefits and increases recreational opportunities will be viewed favourably.

## *A4.3 Select Needs and Opportunities*

The results of the plant survey, in terms of needs and opportunities (life extension and modernization), are now aligned with the plant strategies developed in Section A4.2. Table A4-5 links the companies strategic objectives with the individual plant strategies and the projects proposed.

Following the check in Table A4-5, the Tables A4-3 'Needs' and A4-4 'Opportunities' are now revised to only include those projects which align with the strategies. In this case the 'Needs' projects of Table A4-3 all align with the strategies and a revised table is not required. Similarly the projects in the 'Opportunities' Table A4-4 are also consistent.

**Table A4-5**
**Strategies/Opportunities Link Sheet**

| *UTILITY STRAEGIC OBJECTIVES* | *PERFORMANCE INDICATORS* | *PLANT STRATEGY* | *MODERNIZATION PROJECTS* |
|---|---|---|---|
| **1. Utility strategic objective(s) on investment**<br>Investment will create improvements in the following areas:<br>• Strategic impact<br>• Financial benefit<br>• Environment and social benefit<br>• Risk management | • Shareholder Value Added<br>• Cost of Service<br>• Level of Service<br>• Reportable Incidents | • Improve performance indicators where feasible | • Maintain higher reservoir levels and increase storage<br>• Reduce seepage through dam |
| **2. Utilities strategic objective(s) on market share**<br>Increase market share by:<br>• Trading<br>• Producing additional low cost power | • Cost of Service<br>• Shareholder Value Added<br>• Level of Service | • Improve plant efficiency<br>• Add market products to portfolio | None |
| **3. Utilities strategic objectives on risk management**<br>• Evaluate utility risk exposure<br>• Optimize the utility portfolio exposure | • Shareholder Value added<br>• Risk Portfolio Matrix | • Reduce risk exposure where feasible | • Reduce risk of canal bank failure |
| **4. Utility strategic objectives on stakeholder interests**<br>• Identify all major interests<br>• Evaluate improvement alternatives in light of these interests | • Return on Assets<br>• Shareholder Value Added | • Improve ROA and add shareholder value | None |

| *UTILITY STRAEGIC OBJECTIVES* | *PERFORMANCE INDICATORS* | *PLANT STRATEGY* | *MODERNIZATION PROJECTS* |
|---|---|---|---|
| | | | |
| **5. Utilities strategic objectives on organization and culture**<br>• Utility will foster organizational and public support for its commercial operation | • Organizational Climate<br>• Public Opinion | • Project the organization as an active part of the local community | • Upgrade structural architecture to National Park standards |

### *A4.4 Financial Evaluation*

A financial evaluation of the needs and opportunities projects summarized in Table A4-3 'Needs' and A4-4 'Opportunities' is normally conducted for the entire plant. In this way costs, benefits and timing for the selected Needs and Opportunities are assigned along with the plant's income and cost forecasts.

For the complete plant, the values assigned to the projects form the basis of the input to the financial model, with the outputs forming the basis of the plants business case justification.

In this case, only the civil components are covered and a financial evaluation will not be developed. however, an example of a complete Case History is provided as Appendix C of Volume 1 of these guidelines.

### *A4.5 Life Extension and Modernization Plan*

A life extension and modernization plan is formulated at the completion of the financial evaluation. For the purposes of this Case History, it is assumed that the financial evaluation has identified that life extension for the plant is an attractive option. Similarly, the modernizaton options investigated are attractive under present economic values.

The life extension and modernization plan to be taken forward to the feasibility stage includes the life extension activities and the modernization opportunities listed in Table 4-3 'Needs' and Table A4-4 "Opportunities", respectively.

## A5 Feasibility

### *A5.1 Options for Feasibility*

The Life Extension and Modernization Plan (the Plan) summarized in Section A4 brought forward thirteen activities for life extension and four for modernization.

In most cases the life extension activities are straightforward, representing assessments, repairs and replacements. Only the assessments will be covered in the summary of the feasibility process.

Three assessments are selected as both significant and having a number of possible options and of the process for these will be summarized.

- Seepage control for composite concrete faced rockfill dam

- Architectural improvements to structures to meet National Park standards
- Replacement flashboards to improve storage and provide reliability

In each case, alternative methods will be defined and estimates made of costs and benefits. The preferred alternative will be selected based on meeting technical, economic and environmental criteria.

## *A5.2 Assessments, Tests and Analysis*

For the three projects selected, assessments, tests and analysis include:

- Seepage control for dam
  - Measurements of seepage through dam
  - Assessment of flow-through capability of rockfill dam
  - Underwater surveillance of face of dam to identify cracks
  - Economic evaluation of losses
  - Buildability assessment based on reservoir fluctuations
- Architectural improvements to powerhouse and spillway
  - Seismic evaluations of the powerhouse and spillway structure to determine stability and the need for strengthening
  - Sampling and analysis of concrete possible subject to AAR to determine need for and type of repair
  - Functionality of the structures for future operation
  - Economic evaluation of improvements
- Flashboard alternative to increase storage and reliability
  - Flood routing to evaluate increased storage potential
  - Seismic evaluation and AAR testing of spillway crest and piers
  - Flood capability for different alternatives

In addition to assessment, tests and analysis, an evaluation of the issues associated with each alternative is made.

Environmental impacts relate primarily to proposed changes to the flashboard alternatives. There will be no increase to maximum reservoir levels, only an increase in the duration that the reservoir will be at this maximum level. The return period and magnitude of floods passing over the spillway will not change significantly. Therefore environmental impacts are considered to be minor.

Social impacts relate primarily to the proposed architectural improvements to the significant structures. Bringing these to the same standards as other Park buildings is considered an improvement.

Regulatory and licensing requirements are not expected to change as operation of the facilities and water use will not change. A risk analysis of the proposed activities identified none that were deemed unacceptable.

## *A5.3 Evaluation of Options*

Options were evaluated for each of the three significant actives that are included in the Plan. These are by no means an exclusive list of alternatives, but provide an example of the process under consideration. For each example, reference is made to the relevant section of Chapter 3 Innovative Technologies, in the ASCE Guide.

Seepage Control for Composite Concrete Faced Rockfill Dam

(Chapter 3 Section 3.3 of the ASCE Guide)

Alternative options considered to reduce the seepage through the dam were in two primary areas; replacing the existing facing or sealing with a geomembrane.

Replacing the existing facing requires a full reservoir drawdown for a significant period of time. With the arrangement of outlets and the inability to control inflows, this option would have required a significant cofferdam or other works and the costs would have been higher. Consideration was given to partial replacement of the face but the likelihood on continued excessive seepage would remain high. This option was not considered further. There are a number of geomembrane materials and suppliers available who can undertake this work either in the dry or partly or fully underwater.

The lateral extent and coverage of the geomembrane was estimated and performance specifications determined. Based on the manufacturers budget estimates, the choice between underwater construction methods and a longer schedule involving two or more annual partial drawdowns was close. The option with a full geomembrane placed underwater was selected at the feasibility level, however the final selection will be made based on tenders that meet the required specification.

Architectural Improvements to Structures to meet National Park Standards

(Chapter 3 Section 3.6 of the ASCE Guide)

The primary considerations in the selection of alternative architectural option for the spillway and powerhouse were management of the ageing concrete and meeting seismic loading requirements. This was complicated by the likelihood of AAR activity and the National Park standards in place.

The spillway has less evidence of ageing concrete and seismic withstand was not a problem. The architectural requirements were mainly harmonizing repairs with the existing structure and landscaping to minimize visual impact.

The powerplant has some areas of severe concrete spalling, water damage and staining and vegetation in cracks. In addition, a preliminary seismic evaluation indicated areas of concern for the interior columns and floors. The architectural requirements were primarily cleaning, repairing

spalls and sealing deteriorated membranes. Coloured concrete sealers that matched the exterior were used and vegetation removed. Seismic improvements would be limited to the interior of the structure.

Replacement of Flashboards to improve storage and increase reliability

(Chapter 3 Section 3.5 of the ASCE Guide)

Alternatives were considered to replace the flashboards with a more reliable option which would maintain full reservoir levels for most of the year. After a review of options that meet the requirements, two types were selected, inflatable rubber dams and fuse gates.

Based on both cost considerations and reliability the fusegate option was selected. This would allow the reservoir to be maintained at full pool, subject to inflows, while ensuring that floods would be routed safely.

### *A5.4 Optimization of Options*

For the same reasons as noted in Section A4.4, it is not possible to evaluate the options from an economic/financial perspective without consideration of the complete hydro plant. An example of optimization of options can be found in Appendix C of Volume 1.

### *A5.5 Selection of Feasible Project*

Based on the assumption that the selected options have a net added value, the life extension and modernization activities are documented in a feasibility report. This includes:

- A description of the work proposed
- An estimate of project costs, benefit and schedule
- A summary of licencing and other issues
- A finance, risk and insurance plan
- An implementation plan

## A6 Project Definition and Implementation

The feasibility process provided a modernization approach with proven technical and financial viability. A Project Plan ensures that an outline exists of how the project would be undertaken including a summary of responsibilities, authorities, costs, schedules and deliverables. Confirmation of the plant owner's requirements concerning the modernization of the plant and a Quality Plan also form part of the Project Plan.

### *A6.1 Licensing*

The activities discussed in this case history would have no effect on the mode of operation of the Hydro Plant, and there would be no effect on the rated generator capacity of the plant. Therefore, a non-capacity related amendment to the license would be required.

The non-capacity related amendment process involves a letter to FERC describing the purpose and scope of the amendment requested and includes any relevant correspondence from resource agencies. Amended license exhibits are also submitted.

The license amendment is received from FERC allowing the project to proceed. No other regulatory approvals are required.

Note: It is recognized that the licensing portion of the process will generally be far more involved that the scenario presented here. The purpose of the Case History is to demonstrate the process involved with using the Guidelines. Recognizing that licensing issues associated with any one plant are unique, it is considered that a detailed licensing scenario would not serve to demonstrate the process any better than a high level scenario.

## *A6.2 Financing*

The project activities will be financed internally by the utility. The utility's policy has been to utilize this process across its portfolio of plants and this allows all similar projects to be ranked internally and capital finds to be allotted to the most favourable projects across the portfolio of assets. The hydro project is ranked highly and the necessary capital funds are allocated but will not be finally approved for expenditure until later in the implementation process.

## *A6.3 Project Approval*

Project approval is sought with a detailed submission to the appropriate level of management within the utility. An initial level of approval was gained with the allotting of capital funds towards the project. A detailed submission for the commitment of funds for engineering and detailed design is sought at this time. A further submission will be required at a later for the commitment to contracts covering the supply and installation of equipment and construction of civil works.

## *A6.4 Engineering*

Of the seventeen original initiatives identified for life extension and modernization, eleven require physical improvements. The next phase will be:

- direct replacement of structure or equipment,
- identified work that can be directly from suppliers, or
- engineering design leading to procurement and construction

(a) Direct Replacement

The spillway debris boom has reached the end of life and needs to be replaced. Existing engineering design criteria, drawings and contract documents can be used as they meet present standards and methods.

(b) Identified Work Activities

Some activities are relatively straightforward and require little engineering beyond defining the work and the implementation process. Therefore the engineering components would be relatively small for work items such as; removing rocks and debris from the penstocks, adding drains in the powerplant, installing differential pressure monitoring devices across the trashracks.

(c) Engineering

Activities which require a definition stage engineering study include:

- the powerplant and spillway structures that have to meet National Parks standards
- design of fusegate structures on existing spillway to replace the flashboards
- solutions to AAR related damage to the powerhouse and spillway
- design of geomembrane to alleviate seepage and stability concerns for the dam
- solutions to canal leakage and slope stability

As part of engineering, cost estimates are provided to a level of accuracy commensurate with the requirements of the approval process.

## *A6.5 Procurement*

The procurement process for undertaking the life extension and upgrade activities involves:

- Preparation of tender documents
- Issue of tender documents on an open tender basis
- Receive tenders and selecting preferred bidder
- Award of contract

For the work, procurement was divided into three separate contracts;

A. General Contractor, covering; spillway debris boom, removing debris from penstock, adding drains to powerplant, installing pressure monitoring devices across trashrack, upgrading powerplant and spillway to meet National Park standards, and repairing AAR damage to these structures

B. Specialist Contractor; covering; removing of flashboards, modifications to spillway and installation of fuse gates.

C. Specialist Contractor, covering geomembrane facing to dam and seepage control for canal sections.

## *A6.6 Construction*

Following receipt of the tenders, the work is awarded and construction takes place as specified in the contract documents.

## *A6.7 Documentation*

The entire project definition and implementation process is documented in a design/construction report. The purpose of the report is to provide a record of the work and the process which, due to the longevity of hydro plants, will be a useful record when the life extension and modernization process is revisited in the future. The report includes:

- Design criteria
- As-built drawings
- Changes
- Test results
- Deficiencies
- Photographs

Revised operating and maintenance manuals are also provided to update the existing manuals. These include information regarding the modernized plant's performance data, troubleshooting information and maintenance requirements.

# *B*
# LITERATURE REVIEW

INDEX


| KEY FOCUS | ARTICLE NUMBER |
|---|---|
| General References | 1 to 4 |
| Reservoirs | 5 to 8 |
| Dam, Spillways & Intakes | 9 to 37 |
| Dam Safety | 38 to 55 |
| Spillway and Intake Gates, Hoists, Debris Booms and Trashracks | 56 to 71 |
| Tunnels and Canals | 72 to 75 |
| Penstocks and Water Conduits | 76 to 89 |
| Powerhouses | 90 to 97 |
| Fish Passage Facilities | 98, 99 |

# Volume 6 Annotated bibliography of literature on Civil Components

## General references

**V 6.1**

| | |
|---|---|
| **TITLE** | **Civil engineering guidelines for planning and designing hydroelectric developments** |
| **AUTHOR** | ASCE **COUNTRY** USA |
| **PUBLICATION** | American Society of Civil Engineers. Hydropower Committee of the Energy Division (1995). *Civil engineering guidelines for planning and designing hydroelectric developments,* ASCE, New York. 5 Volumes. |
| **DATE** | 1995 |
| **KEY FOCUS** | Civil components<br>Waterways<br>Dams |
| **SUMMARY** | Volume 1: Planning, Design of Dams & related features & Environmental<br>Volume 2: Waterways<br>Volume 3: Powerhouses and related topics<br>Volume 4: Small-scale hydro<br>Volume 5: Pumped storage and tidal Power |

**V 6.2**

| | |
|---|---|
| **TITLE** | **Engineering guidelines for the evaluation of hydropower projects** |
| **AUTHOR** | FERC **COUNTRY** USA |
| **PUBLICATION** | *Engineering Guidelines for the Evaluation of Hydropower Projects* (1997). Washington, Federal Energy Regulatory Commission Office of Hydropower Licensing. 100p. |
| **DATE** | 1997 |
| **KEY FOCUS** | Refurbishment<br>Evaluation criteria<br>Guidelines |
| **SUMMARY** | Essential reference to the recommended procedures and criteria for reviewing and evaluating hydropower plants in relation to FERC regulations for relicensing. |

**V 6.3**

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|---|---|
| **TITLE** | **Guidelines for public safety at hydropower projects** |
| **AUTHOR** | FERC **COUNTRY** USA |
| **PUBLICATION** | Federal Energy Regulatory Commission. (1992) *Guidelines for public safety at hydropower projects*. FERC, Washington, DC. |
| **DATE** | 1992 |
| **KEY FOCUS** | Licensing<br>Safety |
| **SUMMARY** | Background information to assist with assessment of public safety at hydropower projects. |

**V 6.4**

| | |
|---|---|
| **TITLE** | **Guidelines for rehabilitation of civil works of hydroelectric plants** |
| **AUTHOR** | ASCE **COUNTRY** USA |
| **PUBLICATION** | American Society of Civil Engineers' Task Committee for the Preparation of Guidelines for Rehabilitation of Civil Works of Hydroelectric Plants, *Guidelines for rehabilitation of civil works of hydroelectric plants,* ASCE, New York. 252p. |
| **DATE** | 1992 |
| **KEY FOCUS** | Civil works<br>Rehabilitation |
| **SUMMARY** | Extensive guidelines for rehabilitation of civil works prepared by ASCE. |

## Reservoirs

**V 6.5**

| | |
|---|---|
| **TITLE** | **Design considerations for raising existing dams for increased storage** |
| **AUTHOR** | Bischoff, J. & Obermeyer, J. **COUNTRY** USA |
| **PUBLICATION** | American Society of Civil Engineers.(1993). *Geotechnical practice in dam rehabilitation : Proceedings of a specialty conference sponsored by the Geotechnical Engineering Division of the ASCE, Raleigh, NC.* ASCE, New York, NY. p. 174-187. |

**DATE** 1993

**KEY FOCUS** Reservoirs

**SUMMARY** General discussion on the factors to be considered in designing raises to existing dams: environmental factors, spillway, outlet works, reservoir operation, drainage systems and seismic considerations. Presents 3 case histories illustrating related issues. Illustrated with technical drawings Authors affiliated with Woodward-Clyde Consultants, Oakland CA.

**V 6.6**

**TITLE** **Landslide stabilization at the Clyde Power Project, New Zealand**

**AUTHOR** Brown, R., Gillon, M., & Deere, D. **COUNTRY** New Zealand

**PUBLICATION** American Society of Civil Engineers.(1993). *Geotechnical practice in dam rehabilitation : Proceedings of a specialty conference sponsored by the Geotechnical Engineering Division of the ASCE, Raleigh, NC*. ASCE, New York, NY. p. 299-319.

**DATE** 1993

**KEY FOCUS** Landslide stabilisation
Reservoir slope stability
Reservoirs

**SUMMARY** A review of reservoir slope stability at the 100m high concrete gravity dam of the Clyde Power Project identified ground water conditions which were considered potentially unfavorable for the long-term stability of the slopes. The subsequent US$250 million landslide stabilization program, based on tunnel-based gravity and pumped drainage, is described. Four of the landslides are discussed in detail. Illustrated with technical drawings and tables. Extensive reference list. Recommended reading. Authors affiliated with Clyde Power Project, Electricity Corporation of NZ, Wellington, NZ.

**V 6.7**

**TITLE** **Less is more: minimizing debris in reservoirs to maximize dam safety**

**AUTHOR** Nielsen, Niels. **COUNTRY** Canada

**PUBLICATION** *Hydro Review*. Vol. XIII, No.3,. p. 50-56

**DATE** May 1994

**KEY FOCUS** Dam safety
Reservoirs
Trash management

**SUMMARY** A peer reviewed article detailing BC Hydro's integrated debris strategy to maximize safety, reduce economic losses through head loss and shutdown,

and enhance recreational and commercial uses of their reservoirs. Most of the efforts combine collection and disposal programs with the use of debris booms to protect structures. These are tabled. A debris simulation model constructed for the La Joie plant is described. Author affiliated with BC Hydro, BC.

**V 6.8**

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|---|---|
| **TITLE** | **Remotely Operated Vehicle (ROV) Technology: Applications and Advancements at Hydro Facilities** |
| **AUTHOR** | EPRI **COUNTRY** USA |
| **PUBLICATION** | *Remotely Operated Vehicle (ROV) Technology: Applications and Advancements at Hydro Facilities*. Palo Alto, Calif.: EPRI. [TR-113584-V7]. |
| **DATE** | 2002 |
| **KEY FOCUS** | Surveillance |
| **SUMMARY** | *EPRI's Technology Watch on Remotely Operated Vehicles* provides an excellent coverage of the present state-of-art, how the technology has developed, where it can be used and case histories of successful applications. The Technology Watch also includes descriptions of various methods, their advantages and limitations, and their applicability to various situations. In addition, the report provides a framework for assessing the costs, benefits and opportunities for potential cost savings that might be obtained by using ROV technologies as part of an inspection and maintenance program. |

## Dams, spillways & intakes

**V 6.9**

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|---|---|
| **TITLE** | **Alouette Dam spillway rehabilitation** |
| **AUTHOR** | Holder, Charles & Wilson, David **COUNTRY** Canada |
| **PUBLICATION** | *Uprating and Refurbishing Hydro Power Plants IV. Conference Papers.* International Water Power and Dam Construction: Sutton, UK. p.500-511 |
| **DATE** | 1993 |
| **KEY FOCUS** | Dam rehabilitation<br>Environmental considerations<br>Spillways |
| **SUMMARY** | The rehabilitation of the Alouette Dam spillway was successfully completed within schedule, under budget and without deleterious effect to the environment. The authors attribute the success of the project to the close consultation with all parties interested in the site, planning for minimization of environmental impact, and the flexibility of the plan for implementation to allow for best timing of major earth works. Detailed and well illustrated account of the process followed. Authors affiliated with BC Hydro, BC. |

**V 6.10**

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|---|---|
| **TITLE** | **Cavitation in chutes and spillways** |
| **AUTHOR** | Falvey, Henry **COUNTRY** USA |
| **PUBLICATION** | United States. Department of the Interior. Bureau of Reclamation. (1990). *Cavitation in chutes and spillways*. Bureau of Reclamation: Denver, CO. Water Resources Technical Publication. Engineering Monograph No. 42. 145p. |
| **DATE** | 1990 |
| **KEY FOCUS** | Cavitation<br>Chutes<br>Spillway<br>Tunnels<br>Water conduits |
| **SUMMARY** | Comprehensive technical report, written to provide an understanding of cavitation damage to water conduits, and the design tools necessary to address it. Sections on aeration design and concrete. Uses case studies to illustrate the application of concepts discussed to particular remedial projects. Highly recommended reading. |

**V 6.11**

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|---|---|
| **TITLE** | **Concrete rehabilitation for dams** |
| **AUTHOR** | O'Leary, Sean **COUNTRY** USA |
| **PUBLICATION** | *Waterpower '97. Proceedings of the International Conference on Hydropower.* Vol. 3 ASCE, New York, NY. p 1610-1622. |
| **DATE** | 1997 |
| **KEY FOCUS** | Concrete<br>Dams<br>Rehabilitation |
| **SUMMARY** | Comprehensive paper on concrete deterioration, identification of causal factors, testing and evaluation, and methods of rehabilitation and repair. Author affiliated with Sika Corporation, Lyndhurst, NJ. |

**V 6.12**

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|---|---|
| **TITLE** | **Concrete swelling and reinforcement measures at the Chambon dam** |
| **AUTHOR** | **COUNTRY** |
| **PUBLICATION** | *International Journal on Hydropower and Dams*. Vol. 1, No.2. p 63-66 |
| **DATE** | November 1997 |
| **KEY FOCUS** | Alkali aggregate reaction<br>Concrete<br>Dam rehabilitation |
| **SUMMARY** | Technical article on the remedial measures taken to address the severe cracking problems at Chambon dam, in the French Alps, caused by concrete swelling. |

**V 6.13**

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|---|---|
| **TITLE** | **A Condition Assessment Methodology for Spillways** |
| **AUTHOR** | Chouinard, Luc E. *et al* **COUNTRY** USA |
| **PUBLICATION** | *Waterpower XIII: Advancing Technology for Sustainable Energy, July 29-31, 2003, Buffalo, New York, USA. Technical Papers.* [CD-Rom]. Kansas, MO.: HCI |
| **DATE** | 2003 |
| **KEY FOCUS** | |

**SUMMARY** While developed specifically for the evaluation of gated spillways, it also can be used to prioritize maintenance activities.

**V 6.14**

**TITLE** **Crack Repair in Concrete Dams: Identifying Effective Methods and Materials**

**AUTHOR** Saleh, Kaveh *et al* **COUNTRY**

**PUBLICATION** *Hydro Review*, September 2002, p. 40-49

**DATE** September 2002

**KEY FOCUS**

**SUMMARY** A twelve-year research project has led to an effective and durable solution to "plugging" cracks in one of its concrete arch dams: a new grout injection campaign. Outcomes of the project highlight the importance of understanding the rheological, physical and mechanical properties of different grout media for specific environmental and structural conditions.

**V 6.15**

**TITLE** **A cut above the rest**

**AUTHOR** Gavillet, Michel **COUNTRY** USA

**PUBLICATION** *International Water Power and Dam Construction*. Vol. 50. No. 8. p. 28-9

**DATE** August 1998

**KEY FOCUS** Dam rehabilitation

**SUMMARY** Seepage and internal erosion have been a problem at the Hodges Village Dam, MASS, for 3 decades. Following an extensive evaluation of its condition, a concrete cut-off wall was selected as the solution to the dam's problems and was modelled at both spillway and surcharge pool conditions, and at various wall depths to determine the most effective depth. Equipment used and the process of the renovation is described. Author affiliated with Bauer of America.

**V 6.16**

**TITLE** **Design of fishways and other fish facilities**

**AUTHOR** Clay, C.H. **COUNTRY** *USA*

**PUBLICATION** Clay, C.H.. (1994). *Design of fishways and other fish facilities.* American

Fisheries Society, Bethesda, MD.

**DATE** 1994

**KEY FOCUS** Fishways
Fish safety

**SUMMARY** Design of fishways to reduce fish mortality.

**V 6.17**

**TITLE** **Experience with inflatable weirs at two German small hydro plants**

**AUTHOR** Dumont, U. **COUNTRY** USA

**PUBLICATION** *International Journal on Hydropower & Dams*. Vol. 1, No. 5. p. 80-81

**DATE** September 1994

**KEY FOCUS** Inflatable dams
New technology

**SUMMARY** Experience with both airfilled and water filled inflatable weirs is reviewed. Two case studies are presented, involving difficult operating conditions, one subject to heavy floods and ice loads, the other a heavily polluted river. The devices have proved to be an appropriate technology for fulfilling today's more stringent environmental requirements. Author affiliated with Floeksmüle Energietechnik GmbH, Germany.

**V 6.18**

**TITLE** **French experience of inflatable dams**

**AUTHOR** Leviel, C. **COUNTRY** France

**PUBLICATION** *International Journal on Hydropower & Dams*. Vol. 1, No. 5. p. 78-79.

**DATE** September 1994

**KEY FOCUS** Inflatable dams
New technology

**SUMMARY** Recent developments in materials and the inherent nature of the concept of inflatable rubber weirs make them a flexible option with many applications. The author, affiliated with Satujo SA, France, a company preeminent in the developmemt of inflatable structures, reviews developments and discusses a recent case study.

**V 6.19**

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|---|---|
| **TITLE** | **Guidelines for earthquake design and evaluation of structures appurtenant to dams** |
| **AUTHOR** | USCOLD **COUNTRY** USA |
| **PUBLICATION** | United States Committee on Large Dams. Committee on Earthquakes. (1995). *Guidelines for earthquake design and evaluation of structures appurtenant to dams.* USCOLD, Denver, CO. 75p. |
| **DATE** | 1995 |
| **KEY FOCUS** | Bridges<br>Gates<br>Intake towers<br>Penstocks<br>Seismic evaluation<br>Spillways<br>Tunnels<br>Water conduits |
| **SUMMARY** | This publication addresses the lack of attention given to the effects of earthquakes on spillways, gates, penstocks and other appurtenant structures. Guidelines are presented to assist in the analysis of existing as well a new structures. |

**V 6.20**

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|---|---|
| **TITLE** | **Geotechnical practice in dam rehabilitation** |
| **AUTHOR** | Anderson, Loren (ed) **COUNTRY** USA |
| **PUBLICATION** | American Society of Civil Engineers.(1993). *Geotechnical practice in dam rehabilitation : Proceedings of a specialty conference sponsored by the Geotechnical Engineering Division of the ASCE, Raleigh, NC.* ASCE, New York, NY. 1078p. |
| **DATE** | 1993 |
| **KEY FOCUS** | Dam rehabilitation<br>Dam safety<br>Geosynthetics<br>Monitoring<br>Reservoirs<br>Risk analysis<br>Seismic stability |
| **SUMMARY** | Collection of conference papers on case histories; inspection and monitoring; risk and reliability assessment; increasing reservoir capacity; seepage control; improving stability of dams, foundations and reservoir slopes; rehabilitation for seismic stability; geosynthetics and ground improvement techniques; spillway modifications. Highly recommended reading. |

**V 6.21**

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|---|---|
| **TITLE** | **Guidelines for the design of intakes for hydroelectric plants** |
| **AUTHOR** | ASCE **COUNTRY** USA |
| **PUBLICATION** | American Society of Civil Engineers' Committee on Hydropower Intakes of the Energy Division of the ASCE (1995). *Guidelines for the design of intakes for hydroelectric plants.*, ASCE, New York, N.Y. 475 p. |
| **DATE** | 1995 |
| **KEY FOCUS** | Intakes<br>Trashracks |
| **SUMMARY** | Information on evaluation of existing structures, intake design and features, hydraulic considerations, trashracks, gates, fish mortality mitigation, ice, sedimentation, environmental factors. Comprehensive reference on all aspects of and considerations in the evaluation and design of intakes and their components. Particular emphasis on environmental considerations. |

**V 6.22**

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| **TITLE** | **Heightening or strengthening of concrete dams by means of prestressed anchors- advantages and limitations** |
| **AUTHOR** | Cornut, Roger **COUNTRY** Switzerland |
| **PUBLICATION** | *Uprating and Refurbishing Hydro Power Plants IV. Conference Papers.* International Water Power and Dam Construction: Sutton, UK. p. 450-459. |
| **DATE** | 1993 |
| **KEY FOCUS** | Dam rehabilitation |
| **SUMMARY** | Technical article on the prestressed anchor method, including design principles, technical features, main advantages, safety factors, limits of its application, and main factors to consider for the design and construction. Author affiliated with Swiss Federal Institute of Technology, Lausanne, Switzerland. Recommended reading. |

**V 6.23**

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|---|---|
| **TITLE** | **Improving spillway safety with corrosion-protected anchors** |
| **AUTHOR** | Hasnay, A.H, Rizzo, P. & Myers, T. **COUNTRY** USA |
| **PUBLICATION** | *Hydro Review*. Vol. XVII, No. 3. p. 24-29. |
| **DATE** | June 1998 |
| **KEY FOCUS** | Dam safety<br>Spillways |

New technology

**SUMMARY** Remedial action to stabilize the spillway at the Rio Dam involved the installation of high capacity anchors, corrosion protected by a sheath of 10-inch diameter, heavy wall corrugated polyethylene pipe, a method not used before for anchors of this size. Installation procedures and testing of the anchors is discussed. Author affiliated with Orange and Rockland Utilities, NY.

**V 6.24**

**TITLE** **Installing an underwater geomembrane at Lost Creek Dam**

**AUTHOR** Onken, Steven **COUNTRY** USA

**PUBLICATION** *Hydro Review.* Vol. XVII, No. 3. p. 34-38.

**DATE** June 1998

**KEY FOCUS** Dam rehabilitation
Life extension
New technology

**SUMMARY** The first underwater installation of a geomembrane across the upstream face of a dam, without dewatering the reservoir, proved to be the most cost effective method of extending the dam's life. A detailed account of the process and measurements of the its success are given. Author affiliated with Oraville-Wyandotte District Utility, CA.

**V 6.25**

**TITLE** **Making an automated monitoring system work at Tolt Dam**

**AUTHOR** Marilley, Jill & Myers, Barry **COUNTRY** USA

**PUBLICATION** Hydro Review. Vol. XV, No. 6. p. 10-14.

**DATE** September 1996

**KEY FOCUS** Automation
Dam monitoring

**SUMMARY** As part of its major dam upgrade program, Seattle Water Department installed an automated condition monitoring and advance warning system at Tolt Dam, with positive results from both an operating and public relations perspective. The ADAS (Automated Data Acqusition System) installed and lessons learned from the program, including the effect of severe weather conditions are detailed. Well illustrated.

**V 6.26**

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|---|---|
| **TITLE** | **A New Sealing System for Dams** |
| **AUTHOR** | Lardi, Luciano *et al* **COUNTRY** USA |
| **PUBLICATION** | *Dams – Innovations for Sustainable Water Resources: 22nd Annual USSD Conference San Diego, California, June 24-29, 2002.* Denver, CO.: USSD, p 529-538 |
| **DATE** | 2002 |
| **KEY FOCUS** | |
| **SUMMARY** | A multi-layer sealing system based on PUR ductile plastic successfully addresses long-term dam sealing goals and requirements. Earlier PVC geomembranes had such problems as difficulty with rock anchorage, vulnerability to damage by sun, ice and vandalism, and underseepage when damaged. In this new system, each layer has different characteristics and the layers are integrally bound during setting, with each forming a sealing membrane. It is suitable for various substrates such as concrete, rock or steel, and can be used on very rough substrates such as natural rock face, providing the surfaces are re-profiled first by spraying with shotcrete. |

**V 6.27**

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| **TITLE** | **Plastic bands reduce noise at outlet tunnel** |
| **AUTHOR** | Maugliani, Franco **COUNTRY** Italy |
| **PUBLICATION** | *Hyro Review Worldwide*. Vol. 6, No. 5. p. 30-31 |
| **DATE** | September 1998 |
| **KEY FOCUS** | Noise control<br>Tunnels |
| **SUMMARY** | Italian utility, AEM SPA , has developed a practical device which confines sound waves inside outlet tunnels near Italian plants equipped with Pelton turbines, where noise levels were unacceptably high.The durable reinforced PVC plastic bands, like those used to build flexible doors for warehouses, have dramatically reduced the noise. The design details and mounting procedure is described. |

**V 6.28**

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|---|---|
| **TITLE** | **RCC Construction for Dam Rehabilitation** |
| **AUTHOR** | United States Society on Dams. Committee on Monitoring of Dams and Their Foundations **COUNTRY** USA |

**PUBLICATION** Denver, CO.: USSD, March 2003,

**DATE** 2002

**KEY FOCUS**

**SUMMARY** RCC Construction for Dam Rehabilitation

**V 6.29**

**TITLE** **Rehabilitation of Hodenpyl tailrace retaining walls**

**AUTHOR** Amthor, J.; Roarty, C. J Jr.; Stadnicar, J. **COUNTRY** USA

**PUBLICATION** *Waterpower '97. Proceedings of the International Conference on Hydropower Waterpower*. Vol. 3. (1997). ASCE, New York, NY. p 1600-1609.

**DATE** 1997

**KEY FOCUS** Tailrace rehabilitation

**SUMMARY** A replacement earth retention system, using steel sheet piling and permanent earth anchors, was constructed without demolition of the existing walls, to address freeze-thaw damage of the non air entrained concrete at the Hodenpyl Hydroelectric Station, Michigan. The method saved construction time and reduced environmental impact.

**V 6.30**

**TITLE** **Repair and upgrading of dams**

**AUTHOR** **COUNTRY** General

**PUBLICATION** *International Journal on Hydropower & Dams*. Vol. 3, No. 4. P. 67-77

**DATE** 1996

**KEY FOCUS** Concrete
Dam rehabilitation
Seepage

**SUMMARY** Report on papers presented at the CIGB/ICOLD symposium *Repair and Upgrading of Dams.*

**V 6.31**

**TITLE** **Seepage control in dam rehabilitation**

**AUTHOR** Gould, James & Lacy, Hugh **COUNTRY** USA

**PUBLICATION** American Society of Civil Engineers.(1993). *Geotechnical practice in dam rehabilitation : Proceedings of a specialty conference sponsored by the Geotechnical Engineering Division of the ASCE, Raleigh, NC.* ASCE, New York, NY. 1078p.

**DATE** 1993

**KEY FOCUS** Dam rehabilitation
New technology
Seepage control

**SUMMARY** A detailed, extensively referenced paper on the evidence of developing seepage problems, causative factors and control methods, clearly illustrated with the use of tables. The focus is on remediation techniques developed in the past 20 years, particularly the use of geotextiles and slurry trench procedures. Recommended reading. Authors affiliated with Meuser Rutledge Consulting Engineers, New York, NY.

**V 6.32**

**TITLE** **Spillway Rehabilitation at Dells Hydro: Keys to Economical, Fast-Track Completion**

**AUTHOR** Rudolph, Richard M. & Lawrence L. Campbell **COUNTRY**

**PUBLICATION** *Hydro Review*, March 2003, p. 14-19

**DATE** March 2003

**KEY FOCUS**

**SUMMARY** In replacing the deteriorated spillway deck and hoists at a small hydro plant, an owner faced numerous constraints related to time, economics and river flows. Comprehensive project planning and innovative techniques for demolition and construction were used to complete the project successfully. Removal of the old deck and piers was the most challenging aspect and the method used was a diamond cutting wire saw. This allowed removal in one piece, saved time and avoided material falling into the river.

**V 6.33**

**TITLE** **State of the art hydraulic design of stepped chute spillways**

**AUTHOR** Chanson, H. **COUNTRY** Australia

**PUBLICATION** *International Journal on Hydropower and Dams.* Vol. 1 No. 4. p. 33-42

**DATE** July 1994

**KEY FOCUS** Spillway design
Spillways

State of art design

**SUMMARY** Stepped spillways have inherent advantages associated with rapid energy dissipation, but in recent decades they have been used for handling flood releases, and to increase discharge capacity. This detailed technical paper, extensively illustrated with diagrams and tables, discusses the recent developments in hydraulic design of the spillways, their application to RCC, gabion and earth dams, flow regimes and basic flow patterns. Includes extensive reference list. Author affiliated with the Department of Civil Engineering, University of Queensland, Brisbane, Qld..

**V 6.34**

**TITLE** **The state-of-the-art of RCC dams**

**AUTHOR** Dunstan, M. R.H. **COUNTRY** UK

**PUBLICATION** *International Journal on Hydropower and Dams*. Vol. 1, No. 2, Pp. 44-54

**DATE** March 1994

**KEY FOCUS**
Dams
New technology
RCC dams
Roller compacted concrete
State of art design

**SUMMARY** A comprehensive, technical article on roller-compacted concrete (RCC ) dams. Covers classification types, advantages, design requirements, method of construction and trends in design. Includes extensive reference list and detailed table of key data for all RCC dams at time of publication. Author affiliated with Malcolm Dunstan and Assoc., UK.

**V 6.35**

**TITLE** **Structural modifications at hydro dams: An opportunity for fish enhancement**

**AUTHOR** Mathur, D., Heisey, P., Skalski, J., Hay, S. & Smith, M. **COUNTRY** USA

**PUBLICATION** *Energy and Water: Sustainable Development Proceedings, Congress of the International Association of Hydraulic Research, IAHR* .Vol D (1997). ASCE, New York, NY. p 358-363

**DATE** 1997

**KEY FOCUS**
Fish
Sluiceways
Spillways

**SUMMARY** Hydraulic modeling and detailed physical examination of spillways, in

combination with fish survival information, are necessary if modifications to spillways are going to offer safer fish passage.

**V 6.36**

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| **TITLE** | **The use of prestressed anchors at the Owen Falls refurbishment** |
| **AUTHOR** | Arcangeli, E. & Stella C. **COUNTRY** Uganda |
| **PUBLICATION** | *International Water Power and Dam Construction*. Vol. 45, No. 1. p 23-30 |
| **DATE** | January 1993 |
| **KEY FOCUS** | Dam rehabilitation<br>Refurbishment |
| **SUMMARY** | Severe cracking around the alternator blocks of the generating units at Owen Falls, Uganda, led to the need for the rehabilitation of the dam and power station. A scheme of prestressed rock and vertical anchors was devised . Detailed report of the anchor design, trials and tensioning are given. Extensively illustrated with diagrams, technical drawings and test results. Authors affiliated with RodioSpA, Milan, Italy. |

**V 6.37**

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|---|---|
| **TITLE** | **Using strobe lights, air bubble curtains for cost-effective fish diversion** |
| **AUTHOR** | McCauley, Montouri, L, Navarro, J. & Blystra, A. **COUNTRY** USA |
| **PUBLICATION** | *Hydro Review*. Vol. 15, No. 2. Pp 42-51 |
| **DATE** | April 1996 |
| **KEY FOCUS** | Fish safety |
| **SUMMARY** | A detailed technical article describing the investigation into the use of behavioral barriers to divert fish away from turbines at power plants operated by the Thunder Bay Power Company, Michigan. Strobe lights, with and without air bubbles proved to be a highly effective choice. Authors affiliated with Great Lakes Environmental Center, Flash Technologies, and Thunder Bay Power Company. |

## DAM SAFETY

**V 6.38**

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| **TITLE** | **Analysis of decisions under uncertainty** |
| **AUTHOR** | Schlaifer, Robert **COUNTRY** |
| **PUBLICATION** | Schlaifer, Robert (1983). *Analysis of decisions under uncertainty*. Robert E. Kreiger, Malabar, FLA. 729p. |
| **DATE** | 1983 |
| **KEY FOCUS** | Risk analysis |
| **SUMMARY** | A highly technical introduction to logical analysis of the problems of decision making under uncertainty with the emphasis on the correct formulation of the decision problem, understanding the meaning of the objective and subjective inputs required for the logical analysis of the problem, understanding the meaning of the outputs obtained and methods for exploiting available evidence and checking for consistency. |

**V 6.39**

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| **TITLE** | **Experiences with embankment dam overtopping.** |
| **AUTHOR** | Powledge, George & Pravdivets, Yuri **COUNTRY** USA |
| **PUBLICATION** | *Hydro Review*. Vol. XIII, No. 1. p. 50-59 |
| **DATE** | February 1994 |
| **KEY FOCUS** | Dam rehabilitation<br>Embankment dams<br>Overtopping |
| **SUMMARY** | This peer reviewed, technical article details the case studies of two methods of protecting embankment dams from erosion caused by overtopping: Cellular concrete mats and wedge-shaped blocks have both performed reliably under high-velocity flow conditions. |

**V 6.40**

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|---|---|
| **TITLE** | **Federal guidelines for dam safety** |
| **AUTHOR** | **COUNTRY** USA |
| **PUBLICATION** | United States. Federal Coordinating Council for Science, Engineering, and Technology. Ad Hoc Interagency Committee on Dam Safety. (1979). *Federal guidelines for dam safety.* Ad Hoc Interagency Committee on Dam |

Safety: Washington, DC.

**DATE** 1979

**KEY FOCUS** Dam safety

**SUMMARY** Federal guidelines developed under the auspices of the Federal Emergency Management Agency (FEMA).

**V 6.41**

**TITLE** **Fighting aging in concrete dams**

**AUTHOR** Brighton, R. & Lampa, J. **COUNTRY** Canada

**PUBLICATION** *Hydro Review*. Vol. XVII, No. 6. p. 16-22

**DATE** October 1993

**KEY FOCUS** Concrete dams
Dam rehabilitation

**SUMMARY** Causal factors, analysis methods, and repair and rehabilitation measures for aging concrete dams are discussed, with a key focus on surface damage, joint repairs and improving drain efficiency. Authors affiliated with BC Hydro.

**V 6.42**

**TITLE** **Fusegates Enhance Safety and Increase Capacity at Eikenhof**

**AUTHOR** Shaw, Q.H.W. *et al* **COUNTRY**

**PUBLICATION** *International Journal on Hydropower & Dams*, Vol. 6, Issue Six, 1999, p. 46-51

**DATE** 1999

**KEY FOCUS**

**SUMMARY** A hybrid system using a fixed reinforced concrete labyrinth system on the main spillway and a fusegate system on the auxiliary spillway allowed a dam to be raised 2 m. This combination significantly improved safety levels, as well as significantly increasing storage volumes in the reservoir at a modest cost.

**V 6.43**

**TITLE** **Geotechnical instrumentation supplement**

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|---|---|---|---|
| **AUTHOR** | Greger, J., Taylor, R., Jessop, J., Silevr, M., Spalton, C. & Sorbjan, P. | **COUNTRY** | Various |
| **PUBLICATION** | *International Journal on Hydropower & Dams*. Vol. 4, No. 6. P. 82-87 | | |
| **DATE** | 1997 | | |
| **KEY FOCUS** | Dam safety<br>Geotechnical instrumentation<br>Monitoring<br>New technology<br>Software | | |
| **SUMMARY** | A review of recent technical developments in instrumentation and monitoring sytems and the features and applications software systems for geotechnical data. Case studies from Europe, Africa and Asia are included. | | |

**V 6.44**

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|---|---|---|---|
| **TITLE** | **Geotechnical practice in dam rehabilitation** | | |
| **AUTHOR** | Anderson, Loren (ed) | **COUNTRY** | USA |
| **PUBLICATION** | American Society of Civil Engineers.(1993). *Geotechnical practice in dam rehabilitation : Proceedings of a specialty conference sponsored by the Geotechnical Engineering Division of the ASCE.* ASCE, New York, NY. 1078p. | | |
| **DATE** | 1993 | | |
| **KEY FOCUS** | Dam rehabilitation<br>Dam safety<br>Geosynthetics<br>Monitoring<br>Reservoirs<br>Risk analysis<br>Seismic stability | | |
| **SUMMARY** | Collection of conference papers on case histories; inspection and monitoring; risk and reliability assessment; increasing reservoir capacity; seepage control; improving stability of dams, foundations and reservoir slopes; rehabilitation for seismic stability; geosynthetics and ground improvement techniques; spillway modifications. | | |

**V 6.45**

| | | | |
|---|---|---|---|
| **TITLE** | **Guidelines on risk issues** | | |
| **AUTHOR** | The Engineering Council | **COUNTRY** | UK |

**PUBLICATION** The Engineering Council.(1993). *Guidelines on Risk Issues*. The Engineering Council: London. 48p.

**DATE** 1993

**KEY FOCUS** Risk analysis

**SUMMARY** An overview of some of the issues related to risk management, including professional responsibility, the law (UK), the approach, judgment, management and professional development. “Necessarily framed in general terms and cannot address every situation”. Useful as an introduction to the issues related to this complex area.

**V 6.46**

**TITLE** **Informed decisions**

**AUTHOR** Moxon, Suzanne **COUNTRY** USA

**PUBLICATION** *International Water Power and Dam Construction*. Vol.49, No. 12. p. 34-38

**DATE** December 1997.

**KEY FOCUS** Dam safety

**SUMMARY** A report on the establishment of the National Performance of Dams Program to evaluate the operational and structural performance of US dams and the development of an effective public policy. An overview of the guidelines for the evaluation of dams and “dam incidents” is given.

**V 6.47**

**TITLE** **Probability concepts in engineering planning and design**

**AUTHOR** Ang, Alfredo H-S, & Tang, Wilson, H. **COUNTRY** USA

**PUBLICATION** Ang, Alfredo H-S, & Tang, Wilson, H. ( 1975*). Probability concepts in engineering planning and design*. John Wiley: New York, NY. 2 Volumes, 972 p.

**DATE** 1975

**KEY FOCUS** Probability
Risk analysis
Reliability analysis

**SUMMARY** Written for engineers who want a working knowledge of probability, with mathematical concepts, illustrated through engineering examples. Volume I deals with the basic concepts of probability and statistics essential for modeling engineering problems under conditions of uncertainty. Volume II presents advanced concepts and applications

including statistical decision theory, extreme value statistics, risk and reliability analysis, probability based design and Monte Carlo simulation.

**V 6.48**

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|---|---|
| **TITLE** | **A review of alkali aggregate reaction in hydro plants and dams** |
| **AUTHOR** | Charlwood, R.G. **COUNTRY** Canada |
| **PUBLICATION** | *International Journal on Hydropower & Dams*. Vol. 1. No. 3. p.73-80. |
| **DATE** | May 1994 |
| **KEY FOCUS** | Alkali aggregate reaction<br>Concrete<br>Dam safety |
| **SUMMARY** | This detailed paper analyses the nature and extent of AAR, reviews case histories, looks at available strategies and design options for remedial measures, presents conclusions on the success of actions, and identifies potential future developments. It includes a overview of the GROW3D finite element model which simulates the effects of concrete growth and creep and provides a valuable tool for investigating future structural conditions. Extensive reference list included. Recommended reading. Author affiliated with Acres International, Niagara Falls, ONT. |

**V 6.49**

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|---|---|
| **TITLE** | **Risk-based decision making in water resources V** |
| **AUTHOR** | Haimes, Y, Moser, D. & Stakhiv, E.(eds) **COUNTRY** USA |
| **PUBLICATION** | American Society of Civil Engineers. (1992). *Risk-based decision making in water resources V: proceedings of the fifth conference*. ASCE, New York, NY. 385p. |
| **DATE** | 1992 |
| **KEY FOCUS** | Risk analysis<br>Risk management |
| **SUMMARY** | Collection of papers on risk and reliability, including emerging issues, new methodologies, new software, and risk management related to rehabilitation projects and involving multiple stakeholders. |

**V 6.50**

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|---|---|
| **TITLE** | **Risk management at Wahleach Dam** |
| **AUTHOR** | Salmon, Gary, Cattanach, Dave & **COUNTRY** Canada |

Hartford, Des

**PUBLICATION** *Civil Engineering*, Vol. 67. No. 2.

**DATE** February 1997

**KEY FOCUS** Dams
Dam safety
Risk management

**SUMMARY** BC Hydro developed a risk-based method to make decisions about dam safety improvements. An overview of the risk analysis method and the subsequent modifications is described.

**V 6.51**

**TITLE** **The role of the reservoir in the seismic analysis of concrete dams**

**AUTHOR** Fanelli, M., Fanelli, A., Galimberti, C. & Palumbo, P. **COUNTRY** Italy

**PUBLICATION** *International Journal on Hydropower & Dams.* P.1-76

**DATE** November 1995

**KEY FOCUS** Concrete dams
Dam safety
Seismic analysis
Software

**SUMMARY** It is well known that one of the energy dissipation mechanisms affecting the dynamic behavior of a dam is associated with acoustic radiation from the reservoir bottom. The contribution of this mechanism to the overall damping coefficient is particularly important in the case of a full reservoir, and decreases markedly with lowering of the water level. In this academic paper the authors present a simple numerical procedure for evaluating the overall damping coefficient of a dam from a few basic data. The proposed method has been implemented in a software package for arch dam analysis, DESARC. Authors affiliated with ENEL Center for Hydraulic and Structural Research, ICE (Internet Center of Excellence) and ISMES, S.p.A., Milan Italy.

**V 6.52**

**TITLE** **Searching for Conventional Spillway Control System Alternatives**

**AUTHOR** Bowers, P.W. *et al* **COUNTRY**

**PUBLICATION** *International Journal on Hydropower & Dams*, Issue Three, 2000, p. 37-40

**DATE** 2000

**KEY FOCUS**

**SUMMARY** The use of fusegate systems is another innovative method to improve spillway control. A proposal to raise the operating water level of a dam by over 6 m considered a variety of options. The selected fusegate system forms a watertight barrier at the existing spillway sill. All floods up to a certain pre-determined magnitude will pass over the fusegates, after which they will tip over.

**V 6.53**

**TITLE** **Seismic rehabilitation of earth dams**

**AUTHOR** Marcuson, W., Hadala, P. & Ledbetter, R. **COUNTRY** USA

**PUBLICATION** American Society of Civil Engineers.(1993). *Geotechnical practice in dam rehabilitation : Proceedings of a specialty conference sponsored by the Geotechnical Engineering Division of the ASCE.* ASCE, New York, NY. p. 430-466p.

**DATE** 1993

**KEY FOCUS** Dam safety
Earth dams
Dam rehabilitation
Seismic safety

**SUMMARY** An extensive article on the methods available for engineered remediation of seismically deficient earth dams, (not including tailings dams), their strengths and weaknesses, the case history of their applications. Data from a survey of rehabilitation projects is presented in table format for 36 dams. Four case histories are also presented. Extensively illustrated with technical drawings. Includes bibliography of 39 references. Highly recommended. Authors affiliated with the Geotechnical Laboratory, US Army Engineers waterways Experiment Station, Vicksburg, MS.

**V 6.54**

**TITLE** **Submersible concrete**

**AUTHOR** **COUNTRY** Finland

**PUBLICATION** *International Water Power and Dam Construction*. Vol 48, No 12. p. 24

**DATE** December 1996

**KEY FOCUS** Concrete

Dam rehabilitation

**SUMMARY** To address the problem of erosion of channel walls scientists at Imatran Voima Oy (IVO), Finland have perfected a special-purpose mortar for

carrying out underwater dam repairs. The mortar is more cost effective than traditional damming and drying methods because it can be used in fast flowing water without interfering with power generation. The article describes the features of the mortar, and procedures followed, prior to its application, and in relation to diver safety.

**V 6.55**

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|---|---|---|---|
| **TITLE** | **Upgrading the stability of the Eder masonry dam** | | |
| **AUTHOR** | Wittke, W. & Schroder, D. | **COUNTRY** | Germany |
| **PUBLICATION** | *International Journal on Hydropower & Dams*. Vol. 1, No. 5. p. 57-66. | | |
| **DATE** | September 1994 | | |
| **KEY FOCUS** | Dam rehabilitation | | |
| **SUMMARY** | An 80-100 year extension to the life of the Eder gravity dam has been achieved through the installation of pre-stressed anchors. This technical paper details the preliminary analyses made, the specifications determined, the installation procedures and the quality control program instituted. Strongly supported with tables and figures. Recommended reading. | | |

## Spillway and intake gates, hoists, debris booms and trashracks

**V 6.56**

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|---|---|---|---|
| **TITLE** | **Corps develops new stoplog/bulkhead system** | | |
| **AUTHOR** | Mills, Michael | **COUNTRY** | USA |
| **PUBLICATION** | *Hydro Review*. Vol. XVI, No. 7. p. 74-75. | | |
| **DATE** | December 1997 | | |
| **KEY FOCUS** | Bulkheads<br>New technology<br>Stoplogs | | |
| **SUMMARY** | The USBR, Tulsa, has developed and patented a new stoplog/bulkhead system. Cost is half that of a conventional bulkhead , maintenance and inspection costs are expected to be 80-90% less, and the system combines the advantages of both components. | | |

**V 6.57**

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| **TITLE** | **Debris control at hydraulic structures in selected areas of the USA and Europe** |
| **AUTHOR** | Wallerstein, N., Thorne, C. & Abt, S. **COUNTRY** UK |
| **PUBLICATION** | Wallerstein, N., Thorne, C. & Abt, S. (1996). *Debris control at hydraulic structures in selected areas of the USA and Europe.* Nottingham Univ. Dept. of Geography: Nottingham. 114pp. |
| **DATE** | 1996 |
| **KEY FOCUS** | Trashracks<br>New technology |
| **SUMMARY** | Prepared in cooperation with the Colorado State University Engineering Research Centre, this report focuses on current debris management technology, trashrack and spillway designs, raking equipment and state of art design. Authors affiliated with Nottingham (UK) and Colorado State Universities. |

**V 6.58**

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| **TITLE** | **Ensuring the safety of spillway radial gates** |
| **AUTHOR** | Sarkaria, Gurmuckh **COUNTRY** USA |
| **PUBLICATION** | *Hydro Review*. Vol. XVI, No. 1. p. 48-52 |
| **DATE** | February 1997 |
| **KEY FOCUS** | Safety<br><br>Spillway gates |
| **SUMMARY** | A peer reviewed article on the design, evaluation, seismic considerations, selection and inspection of spillway radial gates. Includes an inspection checklist as well as a discussion of the six major guidelines to follow for ensuring reliability and safety. Recommended reading. |

**V 6.59**

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|---|---|
| **TITLE** | **Guidelines for design of intakes for hydroelectric plants** |
| **AUTHOR** | ASCE **COUNTRY** |
| **PUBLICATION** | Committee on Hydropower Intakes of the Energy Division of the American Society of Civil Engineers. ( 1995). *Guidelines for design of intakes for hydroelectric plants*. ASCE, New York, NY. 475pp. |

**DATE** 1995

**KEY FOCUS** Intakes
Intake gates
Trashracks

**SUMMARY** Information on evaluation of existing structures, intake design and features, hydraulic considerations, trashracks, gates, fish mortality mitigation, ice, sedimentation, environmental factors.

**V 6.60**

**TITLE** **Ice Harbor Dam Intake Gate raise project**

**AUTHOR** Hull, D.; Miller, B. D. & Ochsner, R. **COUNTRY** USA

**PUBLICATION** *Waterpower '97. Proceedings of the International Conference on Hydropower Waterpower*. Vol. 2. (1997). ASCE, New York, NY. p. 1038-1047

**DATE** 1997

**KEY FOCUS** Fish safety
Intake gates

**SUMMARY** Tests conducted by USACE have shown that raising the intake gates, just downstream of the bulkhead slot, 15 to 20 feet above the normal position, improves passage of juvenile fish approximately 10 to 15 percent. The decision process used by the Corps in acquiring and installing the intake gate hoists, and the comparative advantages and disadvantages of mechanical and. hydraulic systems are also discussed.

**V 6.61**

**TITLE** **Latest Maintenance Technologies for Spillway Gates and Steel Penstocks in Japan**

**AUTHOR** Yamamoto, Kosuke *et al* **COUNTRY** USA

**PUBLICATION** *Waterpower XIII: Advancing Technology for Sustainable Energy, July 29-31, 2003, Buffalo, New York, USA. Technical Papers.* [CD-Rom]. Kansas, MO.: HCI

**DATE** 2003

**KEY FOCUS**

**SUMMARY** Effective maintenance of spillway gates and steel penstocks has been identified as a critical factor in the reliable operation of power plants. The move towards performance-based methods for maintenance systems includes reliability-centered maintenance (RCM) and life cycle cost assessment (LCC). Risk assessment of the structural assets is an integral

part of the reliability analysis section of RCM (Maintenance work determination being the other section). Risk assessment is also an integral part of LCC where maintenance decisions are made from an optimum investment perspective.

**V 6.56**

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| **TITLE** | **Modernizing hydro gate hoists for safety and economy** |
| **AUTHOR** | Kmetz, M., Newell, J., & Mochrie, B.N. **COUNTRY** USA |
| **PUBLICATION** | *Waterpower '95. Proceedings of the International Conference on Hydropower.* Vol. 3. (1995). ASCE, New York, NY. p. 2590-2599. |
| **DATE** | 1995 |
| **KEY FOCUS** | Gate hoists<br>Spillway gates |
| SUMMARY | Criteria for evaluation of an existing gate hoist system, and case study of the modernization program at the Piney Hydroelectric Station, Pennsylvania. Authors affiliated with Pennsylvania Electric Company/GPU (Penelec) and Stone and Webster Engineering. |

**V 6.63**

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| **TITLE** | **Out with the old intake gates** |
| **AUTHOR** | Chaput, P., Gawish, D. & Limoges, M. **COUNTRY** Canada |
| **PUBLICATION** | *International Water Power & Dam Construction.* Vol.50, No.1. p. 28-31. |
| **DATE** | January 1998 |
| **KEY FOCUS** | Automation<br>Intake gates |
| **SUMMARY** | As part of the refurbishment of the Beauharnois station 74 gates are being rehabilitated by either replacement, refurbishment of corroded and deformed gate guides, or installation of individual hoists. The inspection and testing methods for the old gates and the process used to determine the refurbished designs is discussed. Charts and diagrams used. Authors affiliated with Hydro-Quebec. |

**V 6.64**

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| **TITLE** | **Planning a cost-effective gate rehab.** |
| **AUTHOR** | Rudolph, Richard & Gundry, James **COUNTRY** USA |

**PUBLICATION** *Hydro Review*. Vol. 15. No. 5. p.10-14.

**DATE** April 1996

**KEY FOCUS** Project planning
Spillway gates

**SUMMARY** Detailed article on the approach taken by Northern States Power Company to the rehabilitation of the 13 self-operating spillway flap gates (each 64ft x 10½ ft) at the Wissota dam project in Wisconsin. The problem identification, testing, model testing, and removal procedures are described. Three gates were repaired to evaluate procedures, costs, schedule safety, and environmental concerns before the next stage was begun. Authors affiliated with Northern States Power Company and Ayres Assoc. Stress the need for planning and on-going evaluation if the rehabilitation process is to be successful. Recommended reading.

**V 6.65**

**TITLE** **Preventing Ice Blockage at Hydro Plant Intakes**

**AUTHOR** Abdelnour, Razek *et al* **COUNTRY**

**PUBLICATION** *Hydro Review*, Vol. XIX, No. 1, February 2000, p. 42-53

**DATE** 2000

**KEY FOCUS** Ice booms

**SUMMARY** The design objective this ice boom is to create a stable ice cover upstream of the boom, thus reducing ice drifting into the intakes.

**V 6.66**

**TITLE** **Preventing slippage of spillway radial gate wire ropes**

**AUTHOR** Flanagan, Tim **COUNTRY** USA

**PUBLICATION** *Hydro Review*, Vol. XVII, No. 3. p. 68-69.

**DATE** June 1998

**KEY FOCUS** Gates
Radial gates
Safety issues

**SUMMARY** The US Bureau of has created a solution to the problem of the slipping of steel wire ropes used to lift and lower radial gates.

**V 6.67**

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| **TITLE** | **Radio-controlled cranes improve operations at Hoover Dam** |
| **AUTHOR** | Wiley, Charles. **COUNTRY** USA |
| **PUBLICATION** | *Hydro Review*. Vol. XIV, No. 4. p. 118-119 |
| **DATE** | July 1995 |
| **KEY FOCUS** | Automation<br>Cranes<br>Control systems<br>Worker safety |
| **SUMMARY** | The addition of remote controls to two cranes in the machine shop and in the turbine gallery at the Hoover Dam has enabled crane operators to make better use of their time an improved worker safety. Author affiliated with USBR, Hoover Dam. |

**V 6.68**

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|---|---|
| **TITLE** | **Recent developments in the automatic clearing of trashracks** |
| **AUTHOR** | Munn, R. **COUNTRY** N.Z. |
| **PUBLICATION** | *International Journal on Hydropower & Dams*. Vol. 3, No. 4. p. 90-91. |
| **DATE** | 1996 |
| **KEY FOCUS** | Trashracks<br>New technology |
| **SUMMARY** | A new type of automatic screen cleaning machine deals with very large influxes of weeds, has rapid continuous response to screen pressure differentials and can operate in any weather conditions at unmanned stations. |

**V 6.69**

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|---|---|
| **TITLE** | **Research study on frazil ice control at a hydroelectric plant** |
| **AUTHOR** | Tarbell, Julia, Cotroneo, G., Peterson, A. & Murray,R. **COUNTRY** USA |
| **PUBLICATION** | *International Water Resources Engineering Conference Proceedings*. Vol. 2. ASCE: New York, NY. p. 1277-1281. |
| **DATE** | 1995 |
| **KEY FOCUS** | Frazil ice<br>Ice |

Trashracks

**SUMMARY**

Three of 5 sections of the trashracks at the Colton Hydroelectric Plant, New York State, were fitted with heaters of varying lengths to study their effect on the formation and growth of frazil ice. Weather parameters and physical data were collected on a PC based system, and the heaters were switched on automatically when specific conditions were met. Unusually mild conditions at the time of the study limited the findings but several inferences can be made and the authors make recommendations for future work.

**V 6.70**

**TITLE** **A Scoring Mechanism for Gates**

**AUTHOR** Doujak, E. *et al* **COUNTRY** USSR

**PUBLICATION** *Uprating and Refurbishing Hydro Power Plants, Prague, December 10-12, 2001.* Dartford, Kent.: *International Water Power & Dam Construction.*

**DATE** 2001

**KEY FOCUS**

**SUMMARY**

A scoring mechanism for the evaluation of spillway gates has been developed using an established software tool. The basic parameters used in the evaluation cover general condition, operating mechanism, condition of surface protection and life expectancy.

**V 6.71**

**TITLE** **Solutions for anchoring steel to underwater concrete superstructures**

**AUTHOR** Riddle, William **COUNTRY** USA

**PUBLICATION** *Hydro Review*. Vol.14, No.7. p. 67-73

**DATE** December 1995

**KEY FOCUS**

Anchors
New technology
Radial crest gates

**SUMMARY**

When four 63 year old radial crest gates at the Saluda Hydroelectric Project, South Carolina had to be replaced, dropping the water level was not an option. The solution was to install temporary stoplog slots which would hold stoplogs in the form of a cofferdam, but a major problems was how to anchor the slots safely and securely while working underwater. The solution, epoxy adhesive anchors, have more general applications for structural repairs which require fastening steel components to concrete superstructures in a submerged condition. This technical paper discusses the innovative technique and the nature of the adhesive in detail. Author

affiliated with South Carolina Electric & Gas Company, Columbia, S.C.

## Tunnels and canals

**V 6.72**

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|---|---|
| **TITLE** | **Buckling capacity of tunnel and penstock liners using finite element analysis** |
| **AUTHOR** | Ahlgren, C & Mattson, R. **COUNTRY** USA |
| **PUBLICATION** | *Waterpower '97. Proceedings of the International Conference on Hydropower. Atlanta Vol. 3.* (1997). American Society of Civil Engineers: New York, NY. Pp. 95-102 |
| **DATE** | 1997 |
| **KEY FOCUS** | Tunnels<br>Condition analysis |
| **SUMMARY** | A technical paper describing the non-linear buckling analysis using the ANSYS code to determine the buckling capacity of sections of the Helms Pumped Storage Project tunnel and penstock liners. The results of the evaluations are presented and illustrated with tables, and comparisons are made to conclusions obtained using more conventional methods of evaluation. Authors affiliated with Pacific Gas & Electric Co., San Francisco, and Structural Integrity Associates, San Jose. CA. |

**V 6.73**

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|---|---|
| **TITLE** | **Friction Reduction of Unlined Power Tunnels for Increased Power and Energy Production** |
| **AUTHOR** | Gass, Matthew **COUNTRY** USA |
| **PUBLICATION** | *Waterpower XIII: Advancing Technology for Sustainable Energy, July 29-31, 2003, Buffalo, New York, USA. Technical Papers.* [CD-Rom]. Kansas, MO.: HCI |
| **DATE** | 2003 |
| **KEY FOCUS** | |
| **SUMMARY** | An innovative approach to reduce frictional losses in an unlined tunnel at a low cost was using a hammer mounted on a small excavator to selectively remove rock projections in the tunnel flow streams. This project had a short payback due both to improvements in the flow regime and the limitation of maximum capacity during peak plant loading. |

**V 6.74**

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| **TITLE** | **Inspection of a hydropower tunnel using remotely operated vehicles (ROV): a 5-year case study** |
| **AUTHOR** | Hosko, Mary Ann **COUNTRY** USA |
| **PUBLICATION** | *Waterpower '95. Proceedings of the International Conference on Hydropower. San Francisco*. Vol. 3. (1995). American Society of Civil Engineers. p. 2645-2653. |
| **DATE** | 1995 |
| **KEY FOCUS** | Condition monitoring<br>Tunnels |
| **SUMMARY** | The tunnel and connected 168m (550ft)penstock at the Raystown Hydroelectric Project, Pennsylvania, have been inspected by a variety of methods often involving costly outages. Following the installation of station markers during a previous dewatered inspection, these have been carried out by different types of Remotely Operated Vehicles (ROV). This paper details each of the ROV methods, costs involved, lessons learned and recommendations for other operators. Author affiliated with Pennsylvania Rural Assocn. and Allegheny Electric Cooperative, Harrisburg, PA. |

**V 6.75**

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|---|---|
| **TITLE** | **Retrofitting outlet tunnel for Blue River Project** |
| **AUTHOR** | Shen, Y., Stow, J., Edmister, T, Falvey, H. & Voight, R. **COUNTRY** USA |
| **PUBLICATION** | *Waterpower '95. Proceedings of the International Conference on Hydropower. San Francisco*. Vol. 3. (1995). American Society of Civil Engineers. p. 1009-1018. |
| **DATE** | 1995 |
| **KEY FOCUS** | Tunnels |
| **SUMMARY** | The retrofit of the Eugene Water and Electric Board's 18.5 ft diameter outlet tunnel at the Blue River Project, was designed to use the existing tunnel to supply water to a penstock and turbine located in a new powerhouse. Previously the flood release was discharged through open channel flow. Proposed modifications included pressurization of the tunnel, penstock, and outlet gates for the combined usage of the flow for both power generation and flood release. A comprehensive physical model study was conducted to assess the effectiveness of the transition.<br><br>This technical paper reports on the preliminary considerations and phases of the model tests undertaken. |

## Penstocks and water conduits

**V 6.76**

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|---|---|
| **TITLE** | **Assessment methodology for steel penstocks** |
| **AUTHOR** | Ahlgren, C., Regan, P., & Mattson, A. **COUNTRY** USA |
| **PUBLICATION** | *Waterpower '95. Proceedings of the International Conference on Hydropower. San Francisco*. Vol. 3. (1995). American Society of Civil Engineers: New York, NY. p. 2197-2206. |
| **DATE** | 1995 |
| **KEY FOCUS** | Penstocks<br>Condition monitoring<br>Testing |
| **SUMMARY** | An evaluation of older penstocks is often hampered by a lack of information available in relation to past standards and construction documentation. This paper summarizes information contained in the ASCE document, *Guidelines for Evaluating Aging Penstocks* (1995), written to bridge this information gap, and presents the principles behind a typical aged penstock evaluation .Authors affiliated with Pacific Gas & Electric Co., San Francisco, and Structural Integrity Associates, San Jose. CA. See also *Guidelines for Evaluating Aging Penstocks.* |

**V 6.77**

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| **TITLE** | **El Dorado Hydroelectric Project- penstock relining case study** |
| **AUTHOR** | Stutsman, Richard **COUNTRY** USA |
| **PUBLICATION** | *Waterpower.'97. Proceedings of the International Conference on Hydropower.* v 1 ASCE, New York, NY, USA. p. 103-111. |
| **DATE** | 1997 |
| **KEY FOCUS** | Rehabilitation<br>Penstocks |
| **SUMMARY** | The physical aspects of relining penstocks with an elastomeric lining material to arrest corrosion and wall loss are discussed. An analysis of project costs is provided. Authors affiliated with the project design engineers and coating contractors. |

**V 6.78**

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|---|---|
| **TITLE** | **Fatigue Critical Areas in Penstocks at Hoover Dam** |
| **AUTHOR** | Todd, Robert **COUNTRY** USA |
| **PUBLICATION** | *Waterpower XIII: Advancing Technology for Sustainable Energy, July 29-31, 2003, Buffalo, New York, USA. Technical Papers.* [CD-Rom]. Kansas, MO.: HCI. |
| **DATE** | 2003 |
| **KEY FOCUS** | Penstocks |
| **SUMMARY** | During the operation of penstocks, fluid structure interaction can result in vibration response, although there are no moving parts. Fatigue damage is a function of loading cycles, and older facilities can become more prone to penstock failure. Operational testing of a vibrating penstock can help determine whether structural degradation is occurring. Analysis can be used to determine remaining service life. |

**V 6.79**

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| **TITLE** | **Finding solutions for preventing leaks in concrete penstocks** |
| **AUTHOR** | Bhat, Param. & Mazza, Mario **COUNTRY** Canada |
| **PUBLICATION** | *Hydro Review*. Vol. 13, No. 6. p. 44-53. |
| **DATE** | October 1994 |
| **KEY FOCUS** | Penstock rehabilitation<br>Water leakage |
| **SUMMARY** | Ontario Hydro faced severe water leakage at ten of its plants where penstocks are constructed of reinforced concrete without steel liners. This peer reviewed, technical article details the investigation of the problems, the repair options and the selected method of repair for the most severely affected units. This involved removing the top section of concrete for the length of the transition section and replacing it with new reinforce concrete after installing a steel liner. Other options may be more suitable for the site where leakage is less severe. |

**V 6.80**

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|---|---|
| **TITLE** | **Guidelines for evaluating aging penstocks** |
| **AUTHOR** | ASCE **COUNTRY** USA |
| **PUBLICATION** | American Society of Civil Engineers' Task Committee on Guidelines for Aging Penstocks. (1995). *Guidelines for evaluating aging penstocks.* |

ASCE, New York, NY. 175p.

**DATE** 1995

**KEY FOCUS** Penstocks
Evaluation guidelines
Testing

**SUMMARY** Covers methods for determining the history of a penstock, procedures for evaluating the existing condition and methods for assessing its future. Testing, safety concerns and guidelines for specific types of penstocks are also included. Case studies are used.

**V 6.81**

**TITLE** **Innovations to Flowline Rehabilitation at PacificCorp Hydro Projects**

**AUTHOR** Atwood, Robert *et al* **COUNTRY**

**PUBLICATION** *Hydro Review*, Vol. XXII, No. 3, June 2003, p. 46-53

**DATE** June 2003

**KEY FOCUS**

**SUMMARY** A wide range of alternatives is available for upgrading water conveyance systems nearing or reaching the end of their useful life. One utility has implemented two different innovative and cost-effective methods. In one case wood-stave pipe has been replaced with 10-foot diameter HDPE pipe, considered to be the most economic solution. The pipe is relatively easy to move with standard hydraulic equipment and can be readily cut in the field using a small chain saw. Concrete was used to construct transition structures where the HDPE pipe interfaced with the existing conveyance system.

At another of its sites, PVC liner was installed in a wood-stave flow-line pipe where excessive leakage was causing substantial losses to power generation, and damage had been caused by a shutdown. Flexible polyester reinforced PVC sheeting, (pond liner) was chosen for use with aluminum hoops at 10-foot intervals. The result was a 90% reduction in leakage, and reduced ground surface erosion. However, when a combination of high velocities and low head pressure subsequently caused damage to an upper section of the liner, the design was modified to reduce liner sag in a second installation of the12-foot diameter wood stave pipe. Additional aluminum flat bars were placed longitudinally to the flow area.

**V 6.82**

**TITLE** **Inspection of steel penstocks and pressure conduits:**

**AUTHOR** USBR **COUNTRY** USA

**PUBLICATION** United States Bureau of Reclamation. *Inspection of steel penstrocks and pressure conduits: Facilities, Instructions, Standards and techniques.Volumes 2-8.* 25p

**DATE** 1996

**KEY FOCUS** Penstocks

**SUMMARY** This detailed guide to the inspection, assessment, testing and evaluation of steel penstocks is available through the USBR website,

http://www.usbr.gov/power/data/fist/fist2~8/2~8cont.htm

**V 6.83**

**TITLE** **Madison penstock rehabilitation**

**AUTHOR** Hildreth, Blaine **COUNTRY** USA

**PUBLICATION** *Waterpower '97. Proceedings of the International Conference on Hydropower* . Vol. 1. (1997). ASCE, New York, NY. p. 124-133

**DATE** 1997

**KEY FOCUS** Penstocks
Rehabilitation

**SUMMARY** Value engineering was used to select the optimal construction method of extending the life of the four 90 year old penstocks at the Madison Hydroelectric Development. The rehabilitation process is described in detail. Author affiliated with Montana Power Company, Butte, MO.

**V 6.84**

**TITLE** **Penstock rehabilitation: developing the right strategy**

**AUTHOR** Kahl, Thomas **COUNTRY** USA

**PUBLICATION** *Hydro Review*. Vol. XVI, No. 2. p. 28-34.

**DATE** April 1997

**KEY FOCUS** Penstocks

**SUMMARY** Safety and operational concerns in relation to aging penstocks can be addressed with an evaluation strategy which takes account of both the technical and economic requirements of its site. Author affiliated with Kleinshmidt Associates.

**V 6.85**

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| **TITLE** | **Relining Conduits with Spincrete** |
| **AUTHOR** | Heinrich, Darrell W. **COUNTRY** |
| **PUBLICATION** | *Hydro Review*, August 2003, p. 64-66 |
| **DATE** | August 2003 |
| **KEY FOCUS** | |
| **SUMMARY** | Faced with leaks in its siphon to a small hydro plant, an owner opted for a trenchless technology using a cement mortar lining called Spincrete. This approach, which applies the cement mortar lining centrifugally, avoided the expense of replacing an extensive length of pipe. The owner expects no maintenance will be required for 20 years on the treated sections, with life extension up to 70 years on certain projects. However, the process has limitations for repairing unsound structures. |

**V 6.86**

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| **TITLE** | **Restoring head gate capabilities** |
| **AUTHOR** | Faisst, K..W. **COUNTRY** Canada |
| **PUBLICATION** | *Hydro Review*. Vol. 10. No. 7.p. 64-72 |
| **DATE** | December 1991 |
| **KEY FOCUS** | Head gates<br>Refurbishment |
| **SUMMARY** | An evaluation of head-gates installed between 1930 and 1955 was conducted at Ontario Hydro's plants. It was found that the self-closing capability of the head-gates at a number older plants no longer existed. Inspection results are given outlining the most common deficiencies along with their suspected causes. Recommendations are also given outlining the best course of action to correct the deficient gates. |

**V 6.87**

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| **TITLE** | **Steel penstocks** |
| **AUTHOR** | ASCE **COUNTRY** USA |
| **PUBLICATION** | American Society of Civil Engineers' Task Committee on Manual of Practice for Steel Penstocks. (1993).*Steel penstocks.* ASCE manuals and reports on Engineering Practice No. 79, ASCE, New York, New York. |
| **DATE** | 1993 |

**KEY FOCUS** Penstocks
Evaluation guidelines

**SUMMARY** The task committee's goal was to review all available penstock literature. The report covers design, manufacture, installation, testing, startup and maintenance of steel penstocks, including branches, wyes, associated appurtenances and tunnel liners.

**V 6.88**

**TITLE** **Using ductile iron pipe for penstocks: a new option**

**AUTHOR** Hurless, Rhett **COUNTRY** USA

**PUBLICATION** *Hydro Review*. Vol. XV, No. 2. p. 34-40.

**DATE** April 1996

**KEY FOCUS** Ductile iron pipe
Penstocks

**SUMMARY** The use of ductile iron pipe for penstock construction at the Wailuku River Hydroelectric Project, Hawaii, is a first for a US hydroelectric plant. Article describes the history of the choice of the material, the material's properties, its performance under pressure conditions, resistance to corrosion, installation considerations, and economics. Author affiliated with Synergics Energy Development, Annapolis, MD.

**V 6.89**

**TITLE** **Utility finds penstock coating provides multiple benefits**

**AUTHOR** Ling, Andy **COUNTRY** Canada

**PUBLICATION** *Hydro Review*. Vol. XVI, No. 5.

**DATE** September 1997

**KEY FOCUS** Penstock coatings
New technology
Latex coatings

**SUMMARY** A new latex coating to reduce rust deterioration and zebra mussel buildup also resulted in a significant increase in unit output. The process and method of application are described.

## Powerhouses

**V 6.90**

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| **TITLE** | **Acoustic peels reduce noise level inside Hillcrest power plant** |
| **AUTHOR** | **COUNTRY** |
| **PUBLICATION** | *Hydro Review.* Vol. XVII, No.6. p.60-62. |
| **DATE** | September 1998 |
| **KEY FOCUS** | New technology<br>Noise reduction<br>Worker safety |
| **SUMMARY** | The Denver Water Department decision to mount sound-absorbing fiber-glass and corrugated steel panels on the interior walls and ceiling of the Hillside Power Plant has led to a significant reduction in noise level, better employee communication and an enhanced work environment. |

**V 6.91**

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| **TITLE** | **Chenaux Generating Station – Tailrace Piers and Wall Rehabilitation Using the Advanced Polymer Encapsulation (APE) System** |
| **AUTHOR** | Deans, John J. *et al* **COUNTRY** USA |
| **PUBLICATION** | *Waterpower XIII: Advancing Technology for Sustainable Energy, July 29-31, 2003, Buffalo, New York, USA. Technical Papers.* [CD-Rom]. Kansas, MO.: HCI, 12p |
| **DATE** | 2003 |
| **KEY FOCUS** | |
| **SUMMARY** | Tailrace piers are prone to distress from the effects of erosion, abrasion and freeze-thaw mechanisms in cold climates. Traditionally, conventional concrete repair techniques have been employed for this sort of deterioration, usually involving the installation of a cofferdam to enable repairs under dry conditions. Recently new methods have been developed for underwater repair of concrete. One such method is Advanced Polymer Encapsulation (APE) which uses a fiberglass reinforced jacket and polymer grout (FRP). |

**V 6.92**

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| **TITLE** | **Concrete Expansion – R.H. Saunders GS Innovative Structural Rehabilitation & Mitigation Effectiveness** |
| **AUTHOR** | Eastman, Keith *et al* **COUNTRY** USA |

**PUBLICATION** *Waterpower XII: Advancing Technology for Sustainable Energy, July 9-11, 2001, Salt Lake City, Utah, USA. Technical Papers.* [CD-Rom]. Kansas City, MO.: HCI

**DATE** 2001

**KEY FOCUS**

**SUMMARY** A large power plant has experienced many operational and structural problems, including decreased generator air gaps and turbine runner clearances, commencing in the 70's. In addition, the powerhouse concrete structure was deteriorating with extensive cracking and water leakage. Concrete expansion due to Alkali-Aggregate Reaction (AAR) was diagnosed as the root cause of concrete movement and ensuing generator and structural problems. A proactive concrete rehabilitation program was implemented to mitigate the effects of AAR induced concrete expansion and repair the concrete structural damage. Slots were successfully cut between the generators along the expansion/contraction joints of the concrete structure, using diamond wire technology. The immediate results were encouraging with reduced compressive stresses in the concrete, increased runner clearances and partial rounding of the throat ring liners. The slots were also sized to provide allowance for future concrete expansion. Numerous innovative techniques were implemented to rehabilitate the structural components that were severely damaged by concrete expansion at the powerhouse, including specialized grouting and sealing technology.

**V 6.93**

**TITLE** **Programming for powerhouses**

**AUTHOR** Wehr, Ulrich & Wehr, Christoph **COUNTRY**

**PUBLICATION** *International Water Power and Dam Construction*. Vol. 49, No. 2. p.27

**DATE** 1997

**KEY FOCUS** Computer-aided design
Powerhouse design
Software

**SUMMARY** A computer program, Computer Aided Power-House Studies (CAPHS), has been developed in FORTRAN and based on AutoCAD, to produce technical drawings and to calculate specification quantities for hydropower caverns equipped with Francis turbines. The range of application for the software is for net heads between 50 and 650m and unit discharge capacities between 10 and 300m3/sec. It can be programmed to handle from two to eight units. Automatic calculation of accurate construction quantities can also be produced.

**V 6.94**

**TITLE** **Recommended practice for hydroelectric plant fire protection**

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| **AUTHOR** | Hathaway, L.R. | **COUNTRY** | USA |
| **PUBLICATION** | *Power Engineering*. Vol.92, no.2, p.48-9 | | |
| **DATE** | Feb. 1988 | | |
| **KEY FOCUS** | Fire protection | | |
| **SUMMARY** | In May 1987 the National Fire Protection Association (NFPA) adopted a new document, ( NFPA 851), *'Recommended Practice for Fire Protection for Hydroelectric Generating Plants'*. The author presents an overview of the contents, and describes how improved power plant design and protection procedures can reduce fire and explosion potential. | | |

**V 6.95**

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| **TITLE** | **Reducing powerhouse noise** | | |
| **AUTHOR** | | **COUNTRY** | United Kingdom |
| **PUBLICATION** | *International Water Power and Dam Construction*. Vol.48, No. 7. p. 35-36 | | |
| **DATE** | July 1996 | | |
| **KEY FOCUS** | New technology<br>Noise control | | |
| **SUMMARY** | Spectrum Acoustic Consultants (UK), have developed a noise control package which involves cladding targeted areas of turbines, and if required, generator sets, with a special acoustic laminate material. This paper discusses the features of the system, considerations preliminary to installation and a Scottish Hydro Electric case study. | | |

**V 6.96**

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| **TITLE** | **Refurbishment of the Inkeroinen power plant** | | |
| **AUTHOR** | Lamminpää J. & Robert, D. | **COUNTRY** | Finland |
| **PUBLICATION** | *International Journal on Hydropower & Dams*. Vol. 1, No. 5. p. 26-27 | | |
| **DATE** | September 1994 | | |
| **KEY FOCUS** | Civil works<br>Powerhouse design<br>Refurbishment | | |
| **SUMMARY** | An innovative engineering solution was used for the refurbishment of the small Inkeroinen plant in Finland. By modifying the hydraulic system it has been possible to retain most of the civil works, and to reduce the number of generating units from four to three, while increasing production by 20%. | | |

The solution adopted included the extension of the old powerhouse to accommodate new electrical machinery and reshaping the water passage to suit the design of the new turbines.

**V 6.97**

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| **TITLE** | **Repainting air intake walls protects generator** |
| **AUTHOR** | Fergusson, G.J. **COUNTRY** Canada |
| **PUBLICATION** | *Hydro Review*. Vol. XIV, No. 3. p. 64 |
| **DATE** | May 1995 |
| **KEY FOCUS** | Paints<br>Powerhouse rehabilitation |
| **SUMMARY** | During a refurbishment program, staff at Manitoba Hydro's Seven Sister Generating Station noticed that paint peeling from concrete walls did not accumulate on the floor but was apparently sucked into the plants' air-cooled generators. The flaking was attributed to high levels of alkaloids in the concrete. A new system of coatings, sealants and paints was designed and applied with excellent results. The system and application procedures is described. |

**V 6.98**

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| **TITLE** | **A New Juvenile Fish Bypass System at Bonneville Dam** |
| **AUTHOR** | Helwig, Lance *et al* **COUNTRY** USA |
| **PUBLICATION** | *Hydro's Future Technology, Markets and Policy, Proceedings of the Waterpower '99 Conference, July 6-9, 1999, MGM Grand Hotel and MGM Grand Conference Centre, Las Vegas, Nevada.* [CD-Rom]. Edited by Peggy A. Brookshier. Reston, VA.: ASCE. |
| **DATE** | 1999 |
| **KEY FOCUS** | |
| **SUMMARY** | Over the last two decades there have been significant changes relating to fish passage around hydro plants. Driven by environmental pressures, re-licensing and competing water use, significant research and development activity has resulted in major improvements using innovative approaches. |

**V 6.99**

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| **TITLE** | **The Use of Physical and CFD Models to Improve Juvenile Fish Passage at The Dalles Dam, TDA, The Dalles, Oregon** |

**AUTHOR** Langeslay, Mike *et al* **COUNTRY** USA

**PUBLICATION** *Waterpower XIII: Advancing Technology for Sustainable Energy, July 29-31, 2003, Buffalo, New York, USA. Technical Papers.* [CD-Rom]. Kansas, MO.: HCI. 2p

**DATE** 2003

**KEY FOCUS**

**SUMMARY** Over the last two decades there have been significant changes relating to fish passage around hydro plants. Driven by environmental pressures, re-licensing and competing water use, significant research and development activity has resulted in major improvements using innovative approaches.